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ASSESSMENT OF ENVIRONMENTAL IMPACTS OF LIGHT-DUTY VEHICLE DIESELIZATION

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16. Abstract

This report provides a first-level assessment of the environmental effects which might result if diesel vehicles in large numbers were produced and sold, thereby changing the mix of vehicles in the in-use fleet so that a substantial fraction were diesel-powered in future years. The study emphasizes the impacts of diesel exhaust emissions on air quality, especially particulates and odor. Impacts are projected to the year 2000, based on several selected scenarios for the growth in diesel population. Two types of air quality analyses are conducted; areawide and local site. The areawide analysis examines pollutant dump effects in three metropolitan city areas. The local site analysis investigates pollutant concentrations in several critical urban sites: the heavily traveled freeway, the street canyon, and the enclosed parking garage. A general description of the methodology is provided. Results are presented in terms of trends in the emission inventories for the city-wide analysis and as pollutant concentration profiles for the local site analysis. The areawide analysis indicates that dieselization would increase urban TSP by less than 3%, while air quality relative to HC, CO and NO_x would improve. The local site analysis shows that dieselization would produce diesel particulate concentrations ranging from 9 to 13 $\mu g/m^3$ at long term exposure locations in the freeway and street canyon sites and 24 $\mu g/m^3$ in the enclosed parking garage. Odor effects in a nominal diesel-gasoline vehicle mix are found to be negligible.

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PREFACE

This report was prepared by the Aerospace Corporation for the U.S. Department of Transportation (DOT), Transportation Systems Center. The report provides a first-level assessment of the environmental effects which might result if diesel vehicles in large numbers were produced and sold, thereby changing the mix of vehicles in the in-use fleet so that a substantial fraction were diesel-powered in future years. This issue is a matter of national concern, since the characteristics and health impacts of diesel exhaust emissions may be intrinsically different from those of gasoline vehicles, which comprise the bulk of the existing fleet.

Because they offer superior fuel economy, diesel vehicles are expected to penetrate all parts of the vehicle market; the report treats this anticipated growth. However, the focus of the work is on dieselization trends in the light duty or passenger car classes of vehicles, which dominate the fleet population.

The technical base for the environmental assessment was developed in two parts. One relates to the determination of fleet emission characteristics for future years. This base was generated from published U.S. Environmental Protection Agency (EPA) emission-effects guidelines, augmented by more recent information pertaining to developments in diesel emission control. The second part relates to the dispersion of pollutant emissions in critical urban sites. Here, the technical base was developed from a review of the report literature on local site field test programs.

The study examines urban air quality impacts due to dieselization, considering effects on both an areawide and local site basis. Three metropolitan regions are investigated: Manhattan, St. Louis, and Phoenix. Air quality impacts are also studied for three typically critical urban traffic sites: the urban freeway, the urban street canyon, and the enclosed parking garage. Effects are projected through the year 2000.

Appreciation is acknowledged for the guidance and assistance provided by Mr. Joseph C. Strum of the Department of Transportation, Transportation Systems Center, who served as DOT/TSC Technical Monitor for this study.

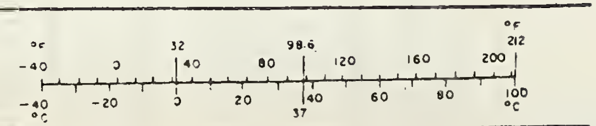
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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GLOSSARY

APRAC	Stanford Research Institute's designation for their atmospheric pollutant dispersion model
BaP	benzo(a)pyrene
BC	base case scenario
C	pollutant concentration, $\mu g/m^3$
CAFE	Corporate Average Fuel Economy
CBD	central business district
CID	cubic inch displacement
CO	carbon monoxide
D	relative measure of odor concentration
DR	dilution ratio
EF	emission factor, g/mi
EGR	exhaust gas recirculation
EPA	U. S. Environmental Protection Agency
f	fraction of diesel vehicles in traffix mix
FTP	Federal (certification) Test Procedure
GM	General Motors Corporation
GVWR	gross vehicle weight rating, lb
HC	hydrocarbons
HDV	heavy-duty vehicles
HDVD	heavy-duty vehicles, diesel
HDVG	heavy-duty vehicles, gasoline
LDT	light-duty trucks
LDTD	light-duty trucks, diesel
LDTG	light-duty trucks, gasoline
LDV	light-duty vehicles
LDVD	light-duty vehicles, diesel
LDVG	light-duty vehicles, gasoline
MVMA	Motor Vehicle Manufacturers Association
NO_x	oxides of nitrogen
PC	passenger cars
PNA	polynuclear aromatic hydrocarbons

Q	traffic emission flux, g/mi-hr
SO_x	oxides of sulfur
SRI	SRI International (formerly Stanford Research Institue)
SWRI	Southwest Research Institue
TC	traffic count, veh/hr
TSP	total suspended particulates
VMT	vehicle miles of travel
ψ	pollutant concentration index, $(\mu g/m^3)/(g/mi\text{-}hr)$

SUMMARY

An assessment was made of the environmental effects which might result if diesel vehicles in large numbers were produced and sold, thereby changing the mix of vehicles in the in-use fleet so that a substantial fraction were diesel powered in future years. The study considered diesel penetration in all parts of the vehicle market including LDV (light-duty vehicles),* LDT (light-duty trucks) and HDV (heavy-duty vehicles), but the focus of the effort was centered on dieselization trends in the LDV class.

The analysis of dieselization effects was conducted on both an areawide (metropolitan) basis and a local traffic site basis. The areawide analysis examined pollutant dump effects in three metropolitan regions: Manhattan, St. Louis, and Phoenix. Pollutants considered were particulates, benzo(a)pyrene (BaP), hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The local site analysis examined pollutant concentration effects for an urban freeway, an urban street canyon, and an enclosed parking garage. Pollutants considered in this work were particulates and diesel exhaust odor. Effects at current (1978), 10-percent, and 25-percent dieselization levels (diesel fractions of LDV and LDT production) and for a fixed HDV dieselization profile (to 100 percent in year 2000) were projected over a 15-year period from 1985 to 2000. In addition to these scenarios, the case for 100-percent dieselization of Manhattan taxicabs combined with 25-percent dieselization of Manhattan passenger cars was also analyzed. Environmental and regulatory factors that could limit the possible number of LDV diesels produced and sold were examined and the resulting loss in national fuel savings was estimated.

The following are brief highlights which summarize (1) the methodology used in the analysis, (2) the results of the pollutant dump and concentration calculations, (3) the assessment of environmental impacts, and (4) the determination of energy penalties due to indicated constraints on the extent of LDV dieselization.

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*Passenger cars or their derivatives, as defined by EPA

S.1 METHODOLOGY

S.1.1 Areawide Analysis

Pollutant dump contributions from all vehicle and stationary sources were accounted for. The dump for each specie was first established for mobile sources, considering vehicles in three classes: LDV, LDT, and HDV; and two engine types: diesel and gasoline. These emissions were aggregated into diesel, gasoline, and total vehicle dumps. Total vehicle emissions were then combined with stationary source emissions to produce the total specie dump for all sources in each regional area.

Vehicle source emissions were determined using a standard, EPA-recommended procedure in which the dump for each specie is calculated from a summation by model year of the product of a model-year-mean emission factor and a model-year-travel fraction, both values representing the vehicle class under consideration. Current and projected vehicle emission factors were based on EPA data or recommendations. This study assumed that particulate emissions for diesel LDV's and LDT's would be controlled to a level of 0.25 g/mi beginning in 1985, while diesel HDV's would remain uncontrolled at 2.0 g/mi. Diesel LDV NO_x was taken at 1.0 g/mi. It was further assumed that diesel emissions would not deteriorate with mileage accumulation (all pollutants). The implications of these assumptions are addressed in the report. A complete listing of the emission factors used in the study is provided. Stationary source emission projections were based on information provided by the cognizant air pollution control authority in each regional area examined.

While not a requirement for the approach taken in calculating vehicle-source pollutant dumps, an explicit determination of the number of vehicles dieselized by projection year was made for the purpose of displaying the nationwide trend of diesel vehicle population growth as impacted by the assumed rates of dieselization. The growth characteristics for LDV's are given in Figure S-1.

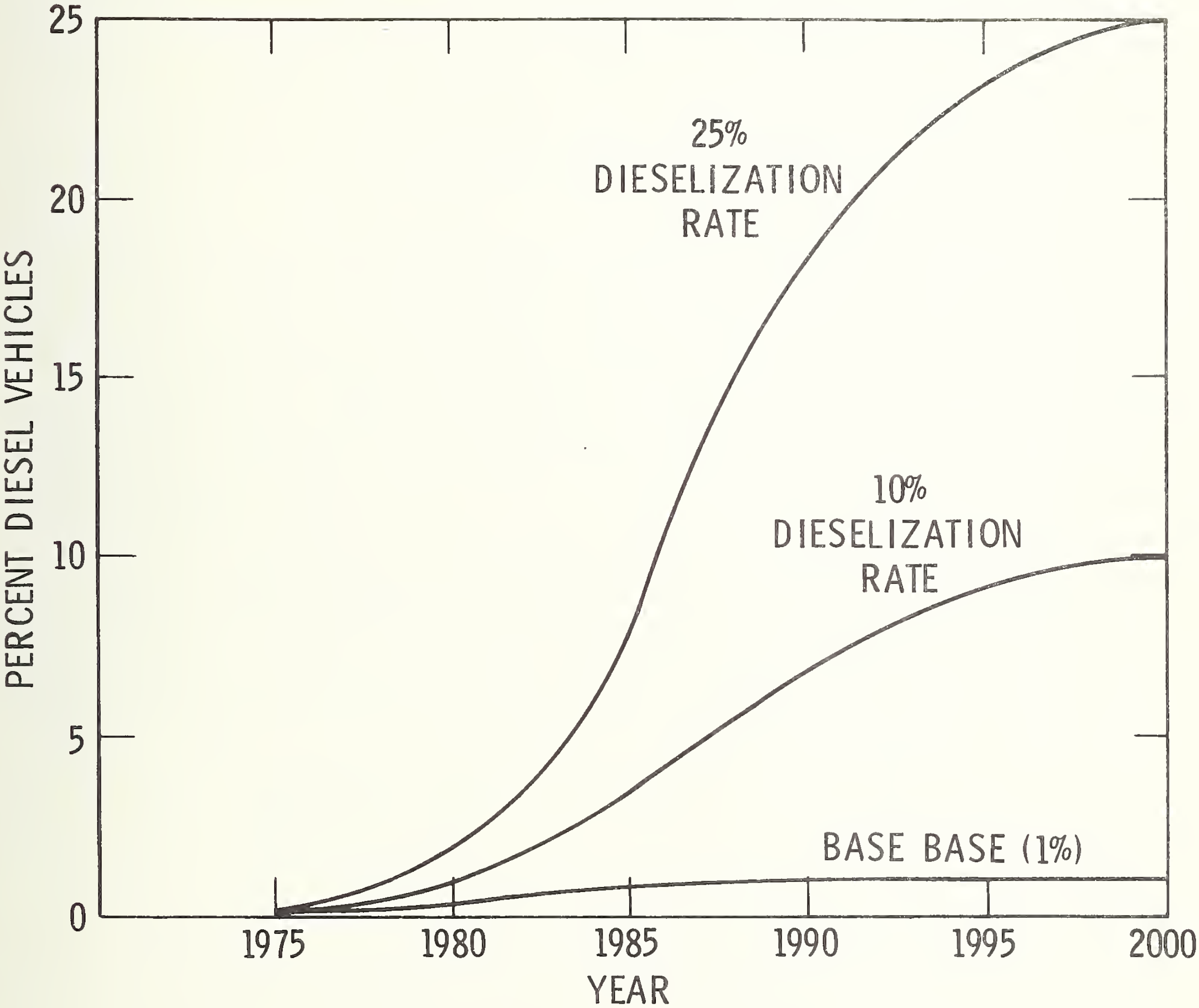

Figure S-1. Diesel Fraction of the Light-Duty Vehicle Fleet (Nationwide)

S.1.2 Local Site Analysis

S.1.2.1 Particulates

S.1.2.1.1 Freeway and Street Canyon

Several basic approaches to the determination of particulate concentrations resulting from road traffic emissions were investigated. This study adopted an empirical approach based on the correlation of roadside-measured pollutant concentration data. These data are expressed in terms of a pollutant concentration index ψ, defined as

$$\psi_{xz} = \frac{\left(C_{xz} - C_b\right)}{Q}$$

where C_{xz} is the concentration of the species measured (CO, tracer gas, or sulfate particulate) at x distance horizontally from the roadway and z distance vertically above the ground, C_b is the specie background concentration, and Q is the vehicle source emission flux from the roadway. The assumption is made that the pollutant concentration index ψ for particulate emissions will be equal to the pollutant concentration index ψ for the test-measured specie. The measured data in each site category, expressed in the form of this index, are plotted as a function of xz and a characteristic ψ_{xz} correlation is established. Particulate concentrations for a given dieselization scenario are then obtained by multiplying the characteristic ψ_{xz} values by the roadway emission flux for particulates at projected traffic conditions. This approach implicitly assumes that vehicle exhaust particulates are sufficiently small to disperse as a gas. The analysis makes no attempt to classify particulate behavior in terms of size distribution or chemical composition. It is realized that this may limit the usefulness of the analysis since diesel particulates are very small and may contain substances with different toxicity levels. However, both the lack of particulate data and the limited scope of the study have precluded consideration of the differences in size distribution of the particulates from the various sources, as well as consideration of particulate composition.

S.1.2.1.2 Parking Garage

An experimental data base suitable for the analysis of the enclosed parking garage could not be found. This site case was treated on a purely analytical basis, considering a closed, ventilated chamber in which pollutant emissions and ventilation air are assumed to be completely mixed in the chamber atmosphere. A closed-form solution to this problem was developed and was evaluated for a range of garage ventilation rates. As for the freeway and street canyon, the analysis approach adopted for the parking garage implicitly assumes that vehicle exhaust particulates behave as a nonreactive gas.

S.1.2.2 Diesel Exhaust Odor

The odor methodology was based on a quantitative assessment of odor by A. Turk of City University of New York (CUNY), and on related tests of public response to diesel exhaust odor conducted by Southwest Research Institute (SWRI). The work by Turk characterized odor in terms of D-numbers ranging from 1 to 12 in order of increasing odor intensity, where the D-numbers are defined by a logarithmic scale of concentration for a reference odorant. The work by SWRI characterized public response to D-numbers and also defined the D-number rating of air-diluted diesel exhaust sampled in various vehicle operating modes.

The approach, then, was (1) to define the D-number rating for the vehicle operating modes in the traffic sites examined, (2) to determine the dilution of the traffic exhaust at site positions of interest, (3) to determine the D-number for the diluted exhaust, and (4) to relate these D-numbers to public response to diesel exhaust odor at these levels.

S.2 CALCULATION RESULTS

S.2.1 Areawide Results

Sample results of the areawide pollutant dump calculations are given in Figures S-2, S-3, and S-4, showing the total dump (mobile plus stationary sources) for Manhattan, St. Louis, and Phoenix, respectively. For all regions, the particulate characteristic appears as a single-valued curve with a slightly decreasing trend relative to the 1975 base year, and with no apparent influence due to LDV dieselization. This lack of visibility relative to LDV dieselization effects is due to the fact that the mobile source contribution is extremely small compared to the contribution from other sources. In

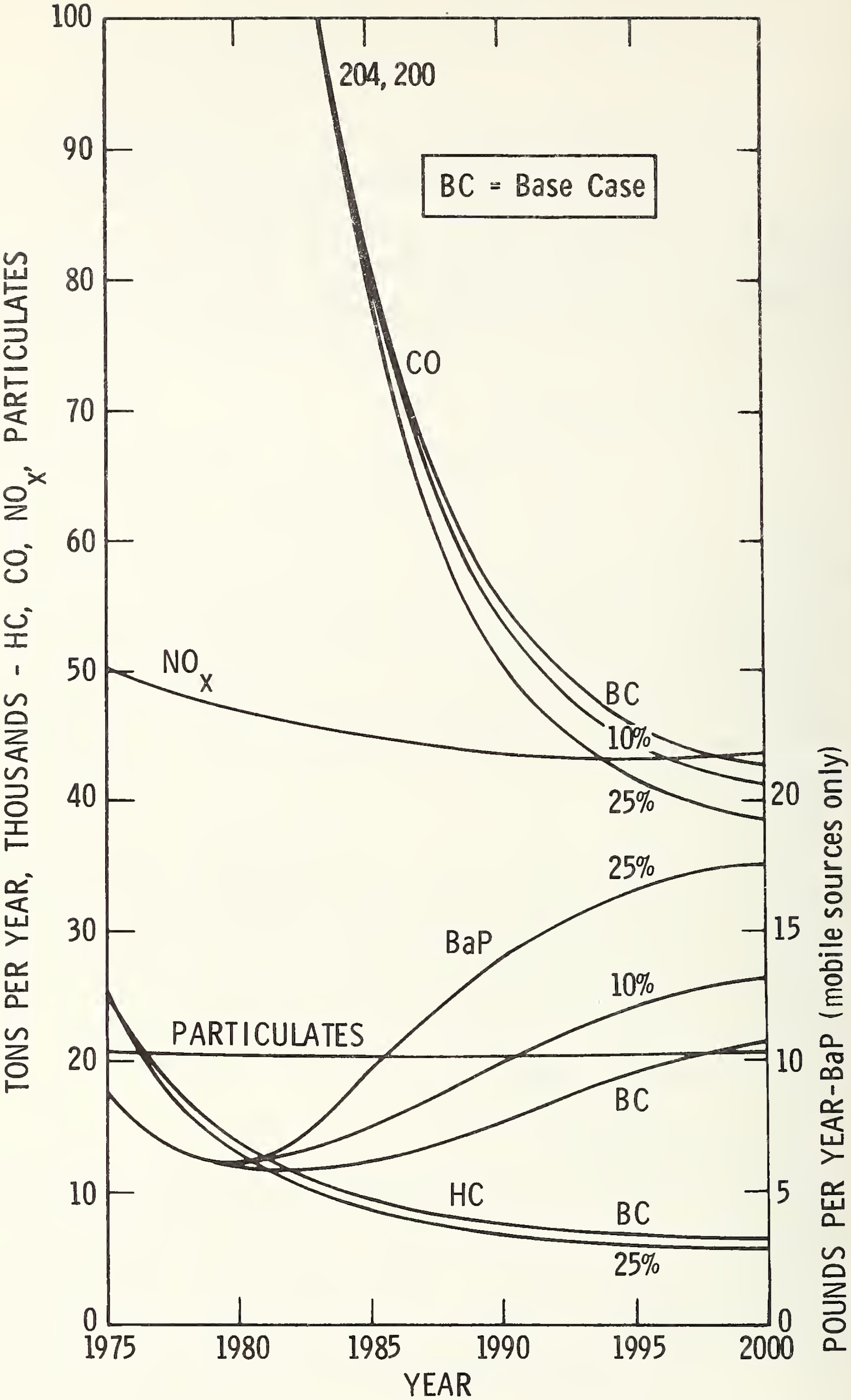

Figure S-2. Manhattan Pollutant Dump--Mobile Plus Stationary Source Contributions

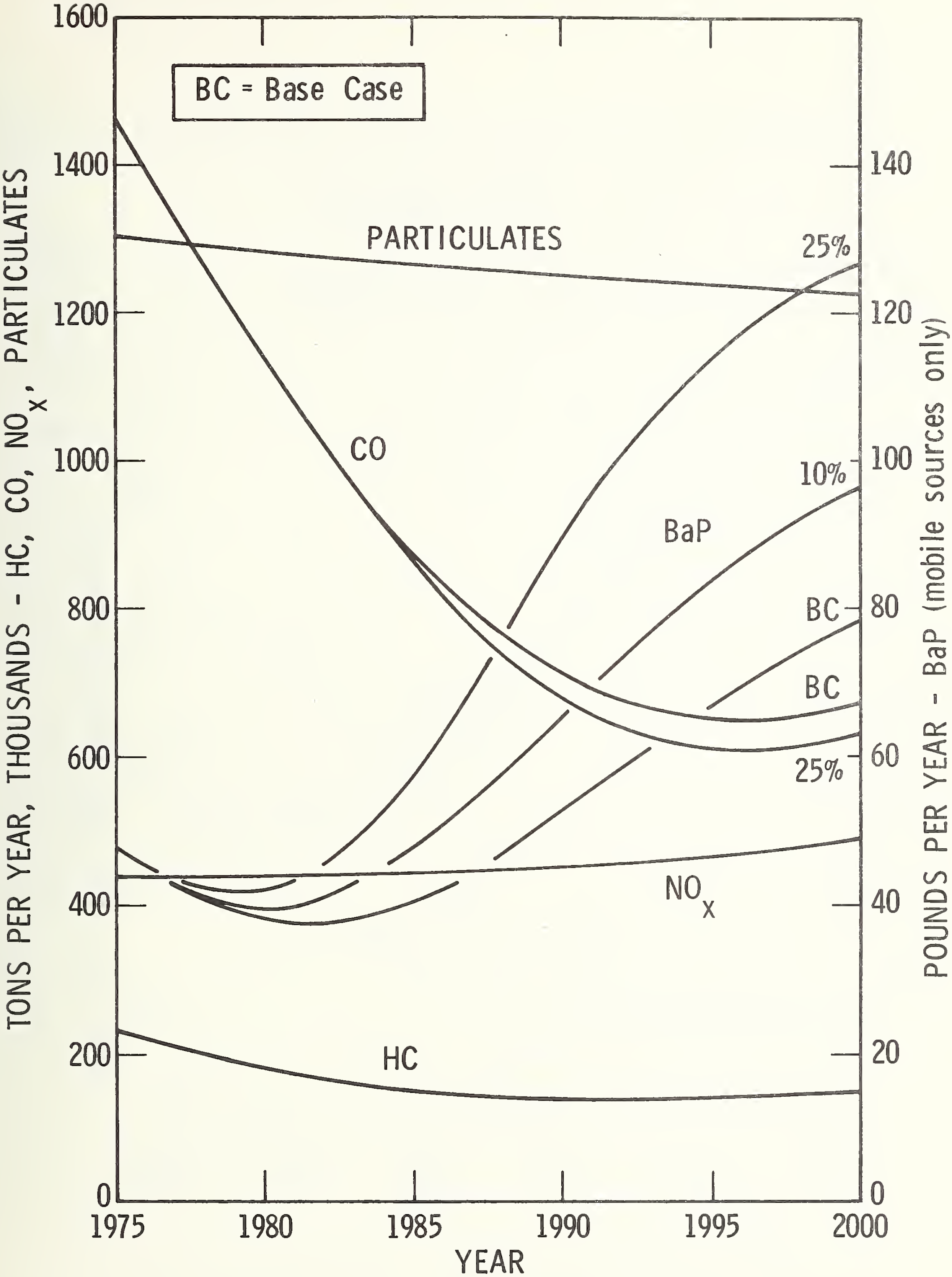

Figure S-3. St. Louis Pollutant Dump--Mobile Plus Stationary Source Contributions

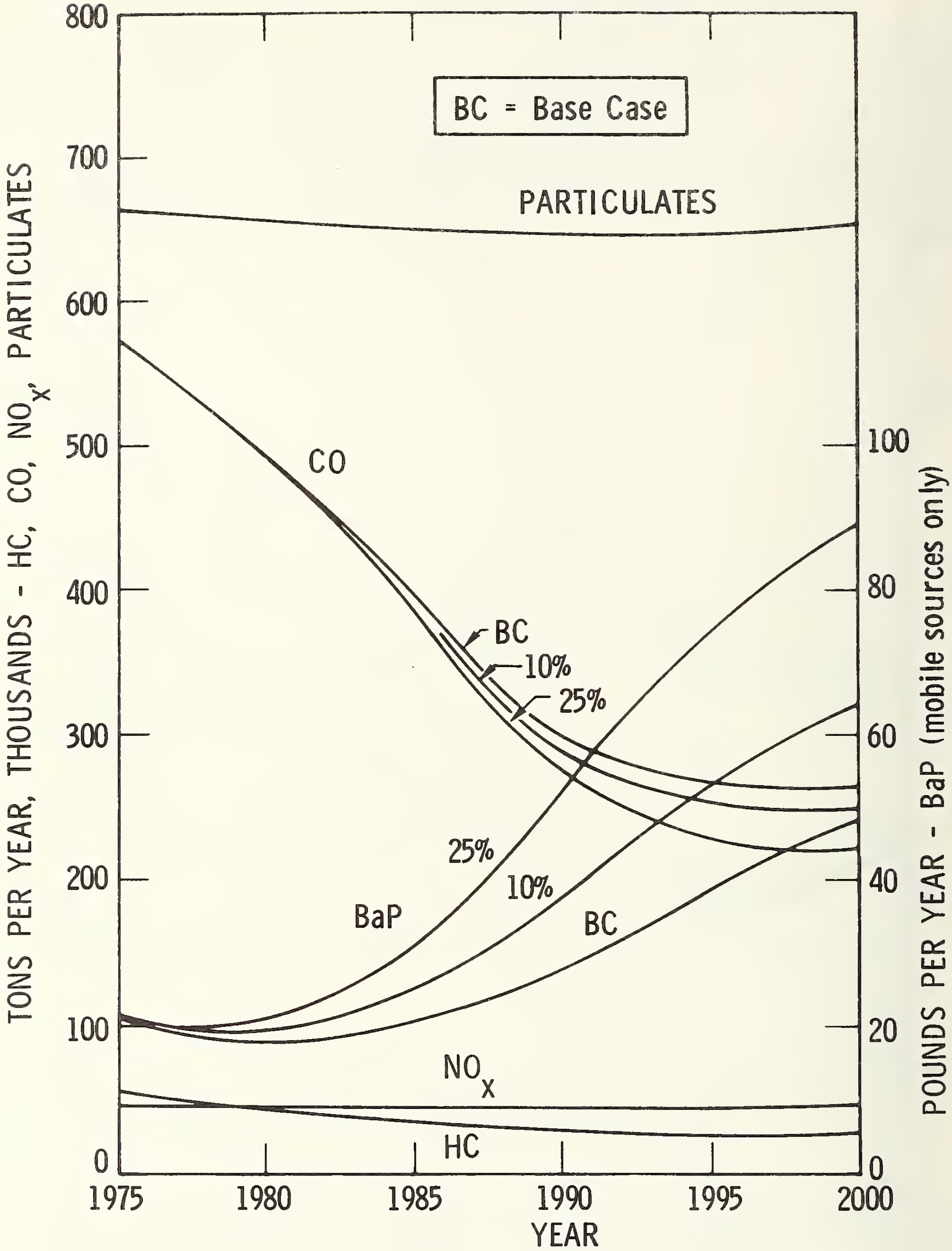

Figure S-4. Phoenix Pollutant Dump--Mobile Plus Stationary Source Contributions

Manhattan, for example, the mobile source contribution in the year 2000 is less than 3 percent of the TSP (total suspended particulate) dump.

Diesel BaP effects were examined at both a low and a high estimate of emission rate. The dump profiles shown in the figures are based on the high estimate and represent only the mobile source contribution to the areawide dump; data on stationary source BaP emissions were not available for the regions examined, nor could they be estimated with reasonable certainty. The BaP characteristics for all three regions show similar trends. The dump reaches a minimum in 1980 and then increases as the fleet population of diesel vehicles grows in the later projection years. The profile for the base case shows a strong increasing trend, reflecting the growth projected for diesel vehicles in the HDV class. The curves show a marked sensitivity to LDV dieselization rate, as would be expected in view of the fact that diesel LDV's emit 10 to 60 times the amount of BaP as do the catalyst-equipped gasoline vehicles which they replace in the later projection years.

For all regions examined, the HC characteristic exhibits a declining trend relative to the 1975 base year, due largely to improved HC control of gasoline-powered vehicles using catalyst devices. Though not visible in the plots for St. Louis and Phoenix because of the scales selected for plotting, the effect of dieselization is to reduce the areawide HC dump. Similar trends are seen for CO.

The NO_x characteristic appears as a single-valued curve which, with reference to the 1975 base year level, descends with projection year in the case of Manhattan, ascends with projection year in the case of St. Louis, and follows a generally level path with projection year in the case of Phoenix. These varying trends reflect differences in the regional projections for growth in stationary source emissions, in combination with the influence of a general decrease in vehicle emissions due to improved NO_x control measures. For Manhattan, the stationary source emission growth is zero; consequently the total NO_x dump declines with projection year, reflecting the trend of vehicle source emissions in a regional area where vehicle miles of travel (VMT) is constant over the time period of interest. For all three regions, the effect of LDV dieselization, though not visible in the plots, is to reduce the areawide NO_x dump.

S.2.2 Local Site Results

S.2.2.1 Particulates

S.2.2.1.1 Urban Freeway

Vehicle exhaust particulate concentrations were computed as a function of projection year for four roadway positions: the median position, and positions at 13, 100, and 300 ft from the roadway edge. Of these, only the 300-ft position was identified as a site where possible long-term human exposure effects would occur (private residences). Results for Manhattan at the 300-ft position are displayed in Figure S-5, which shows both diesel-only and total (gasoline plus diesel) exhaust concentrations for all scenario cases including the Manhattan taxi scenario. These results are based on a 50th-percentile correlation of the roadway data base, and are taken to represent frequently recurring effects at rush hour traffic conditions for a heavily traveled freeway (12,000 veh/hr). Diesel concentrations range up to 13.3 $\mu g/m^3$ in the year 2000 for the 25-percent dieselization rate and to 15.5 $\mu g/m^3$ for the Manhattan taxi scenario.* Corresponding vehicle total (gasoline plus diesel) concentrations are 14.2 and 16.3 $\mu g/m^3$. These values, it is noted, represent only the vehicle exhaust emission contribution to particulate concentration in the urban freeway site.

S.2.2.1.2 Street Canyon

Vehicle exhaust particulate concentrations for the street canyon were computed as a function of projection year for three street canyon elevations: street level (6 ft), 30 ft, and 90 ft. Concentrations are highest at street level and decrease with height above street. Results for Manhattan at street level are displayed in Figure S-6, which shows both diesel-only and total (gasoline plus diesel) exhaust concentrations for all scenario cases including the Manhattan taxi scenario. Consistent with the

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*For clarity in reading Figures S-5 and S-6, the diesel-only concentration characteristic for the Manhattan taxi scenario is not displayed.

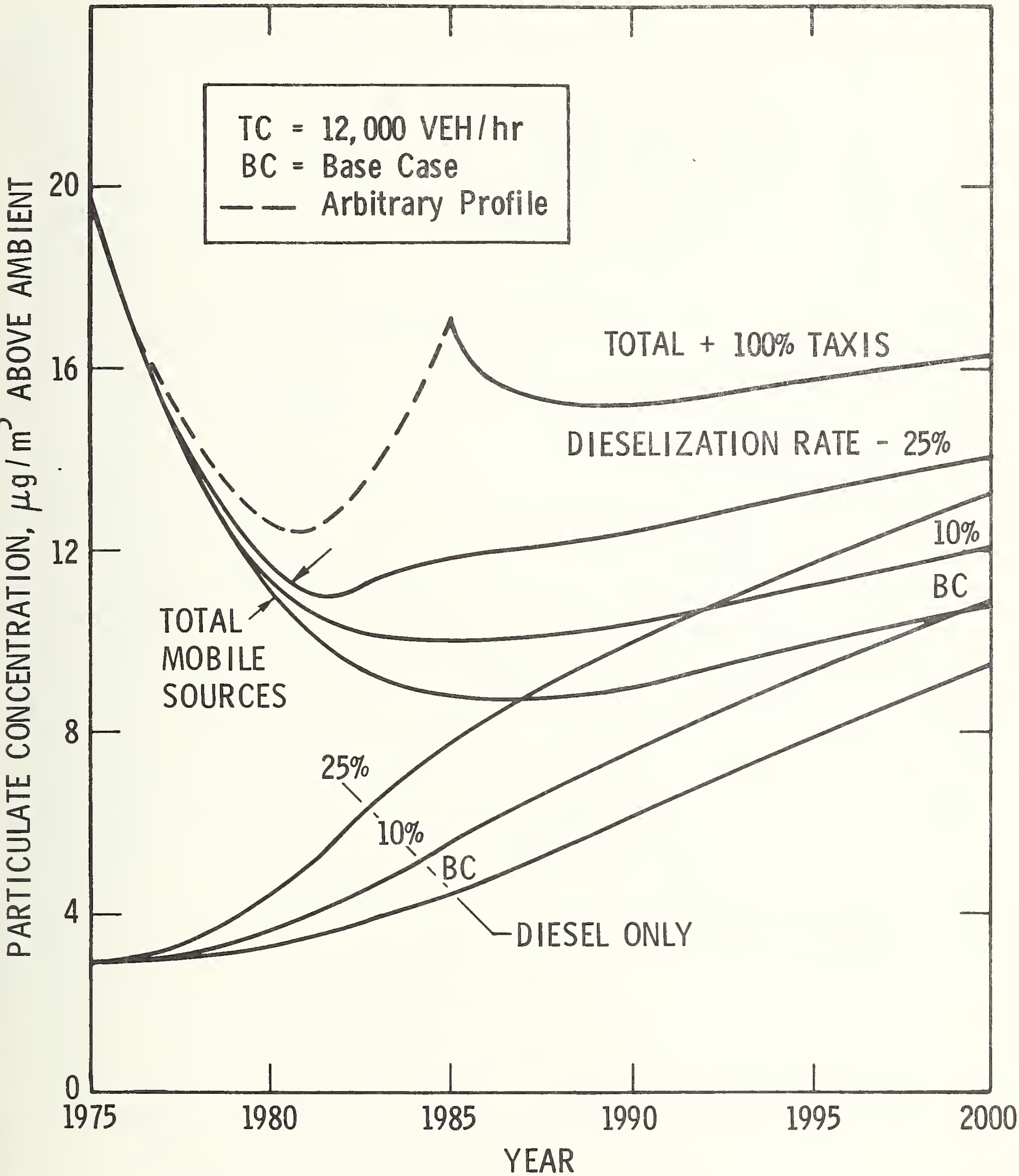

Figure S-5. Urban Freeway Exhaust Particulate Concentrations, 300 Feet from Roadway Edge (Manhattan Traffic Statistics)

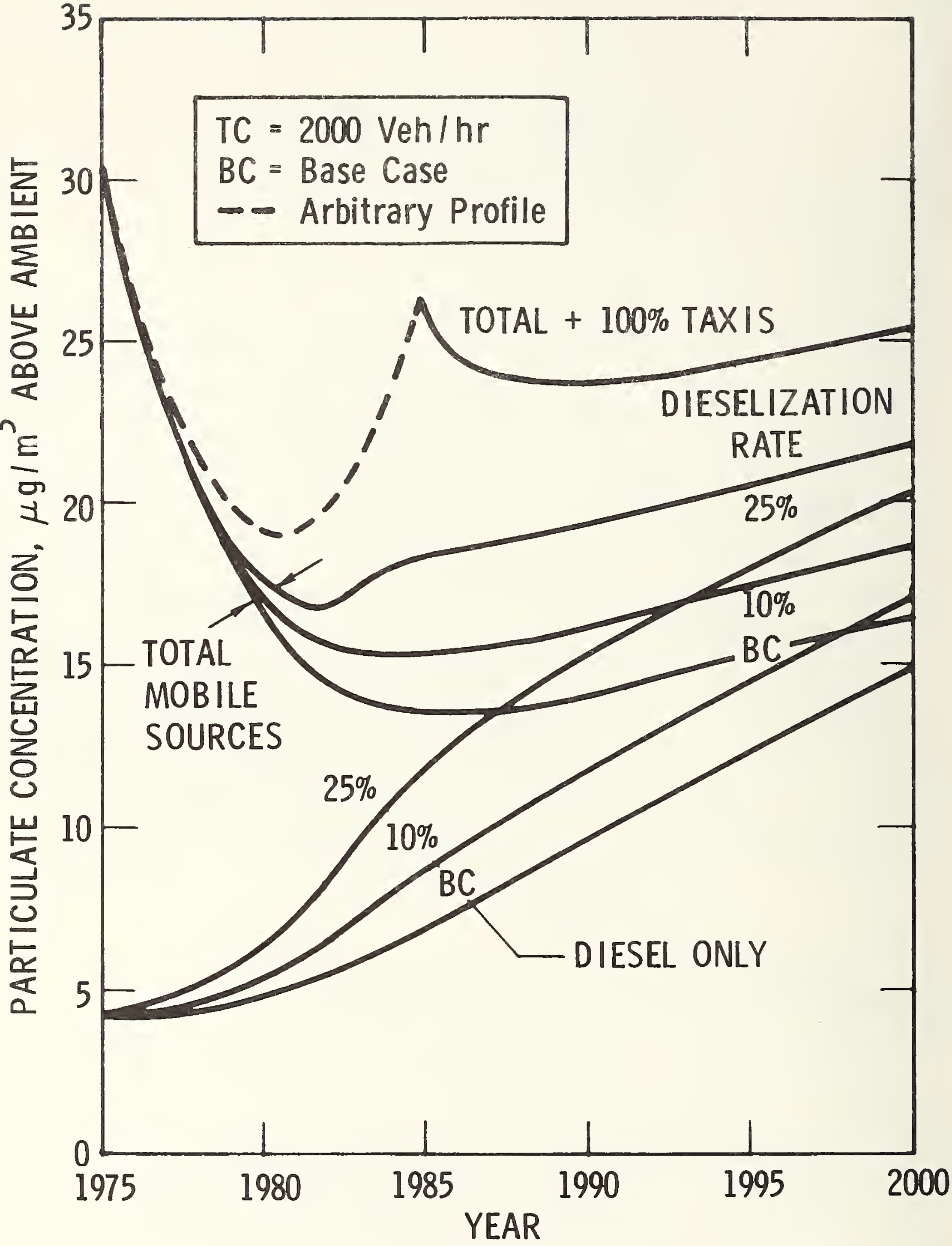

Figure S-6. Street Canyon Exhaust Particulate Concentrations, 6 Feet Above Street Level (Manhattan Traffic Statistics) display for the urban freeway, the results shown are based on a 50th-percentile correlation of the street canyon data base and are taken to represent frequently recurring effects at rush hour traffic conditions (2000 veh/hr). Diesel concentrations range up to 20.5 $\mu g/m^3$ in the year 2000 for the 25-percent dieselization rate and to 23.9 $\mu g/m^3$ for the Manhattan taxi scenario. Corresponding vehicle total (gasoline plus diesel) concentrations are 21.9 and 25.3 $\mu g/m^3$. These values, it is noted, represent only the motor vehicle exhaust emission contribution to particulate concentration in the street canyon site.

S.2.2.1.3 Parking Garage

Particulate concentrations for the parking garage were computed for two different garage activity modes: unrestrained vehicle movement during periods of off-peak garage activity and queuing of vehicles at the garage exit ramps during rush hour periods when the garage exit facilities become temporarily overloaded. The combined effects of both types of activity are shown in Figure S-7 for a mix of gasoline and diesel vehicles at 25-percent dieselization rate conditions in the year 2000. The figure is drawn for total vehicle exhaust emission concentrations, 70 percent of which is contributed by the diesel population. At time zero the garage atmosphere is at the ambient conditions of the incoming ventilation air, gradually builds in concentration level due to off-peak vehicle activity at Y (active vehicle fraction of garage capacity) = 1.5 percent, and stabilizes at a concentration level of 49 $\mu g/m^3$ (diesel exhaust concentration = 34 $\mu g/m^3$) under the condition of a ventilation rate/garage volume ratio of 0.067 min^{-1}. With a large number of cars attempting to exit simultaneously, a queue of idling cars equal to 25 percent of the garage capacity develops. If this condition persists for 15 minutes, the concentration will build to a level approaching 450 $\mu g/m^3$. Assuming no garage activity after this, the concentration will decay as shown. The off-peak Y-value of 1.5 percent, it is noted, represents unusually busy garage conditions; a best-estimate Y would produce concentration levels of about half those indicated for the off-peak mode; i.e., 24 $\mu g/m^3$ and 17 $\mu g/m^3$ for total exhaust and diesel exhaust concentrations, respectively.

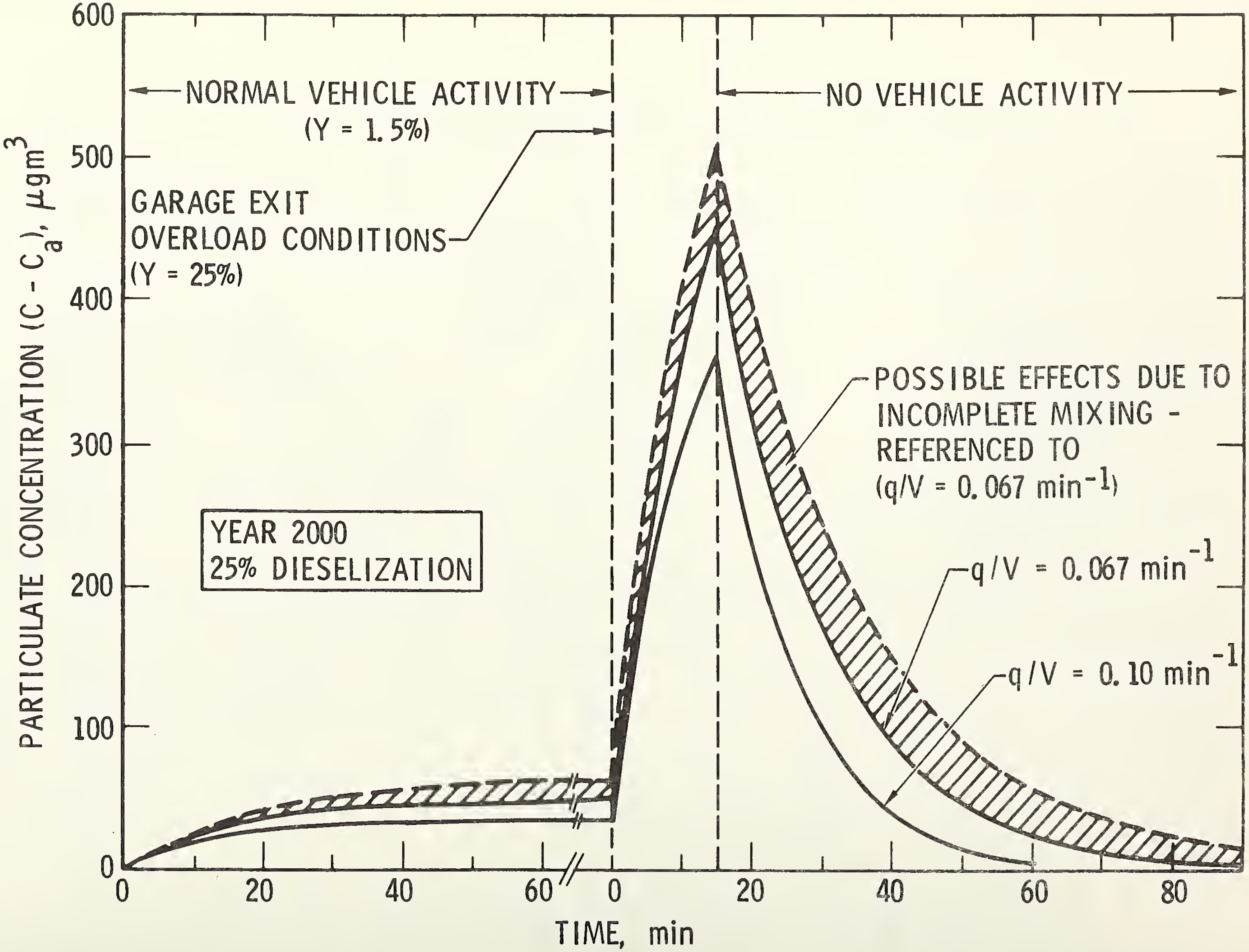

Figure S-7. Particulate Concentration Effects in Enclosed Parking Garage

S.2.2.2 Diesel Exhaust Odor

Odor analyses were performed for the urban freeway, the urban street canyon, and the enclosed parking garage. In each case, the diesel exhaust concentration for the conditions of a nominal average mix of diesel and gasoline vehicles corresponding to the highest dieselization rate considered in this study was found to produce no detectable odor effects. Recognizing, however, that odor levels may be strongly influenced by short-duration localized concentrations and that in any random event a high fraction of diesel vehicles may occur, the case for a 100-percent diesel population was investigated. This investigation yielded ambient D-numbers of 1.5 for the urban freeway (median position), 2.6 for the street canyon (street level elevation), and 1.8 and 4.0 for off-peak activity and overload conditions, respectively, in the enclosed parking garage. At a D-number of 2.0, the lowest value ranked for odor response, 56 percent of the subjects tested evaluated the odor as unpleasant or worse. At a D-number of 3.0, 73 percent of the subjects tested evaluated the odor as unpleasant or worse.

S.3 ENVIRONMENTAL IMPACTS

S.3.1 Areawide Effects

An assessment was made of the impacts on the environment indicated by the results of the regional area pollutant dump calculations. The method of approach was to determine the percentage change in the areawide dump for each pollutant specie, and, assuming that the specie concentration changes proportionally with the mass dump, to draw conclusions as to the effects of dieselization on areawide air quality for the region in question. In the following paragraphs, the terms LDV dieselization and LDV's are used as a convenient shortform to denote vehicles in both the LDV class and the LDT class.

S.3.1.1 Particulates

Parameters pertinent to the assessment of areawide particulate effects in the three regions studied are shown in Table S-1. It may be seen that the effects produced by dieselization in all scenario cases are quite

Table S-1. Areawide Particulate Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year				Percent Contribution				Percent Change From Base Case (BC)		
		Diesel (D)	Total Vehicle (TV)	Combustion Sources (CS)	Total Sources (T)	D/CS	D/T	TV/CS	TV/T	D	TV	T
Manhattan	BC	404	451	11,519	20,452	3.51	1.98	3.92	2.21	---	---	---
	10%	462	506	11,574	20,506	3.99	2.25	4.37	2.47	14.36	12.20	0.26
	25%	556	597	11,665	20,597	4.77	2.70	5.12	2.90	37.62	32.37	0.71
	25% PC + 100% Taxis	651	688	11,756	20,688	5.54	3.15	5.85	3.33	61.14	52.55	1.15
St. Louis	BC	2,964	3,290	70,304	1,221,638	4.22	0.24	4.68	0.27	---	---	---
	10%	3,357	3,667	70,681	1,222,015	4.75	0.27	5.19	0.30	13.26	11.46	0.03
	25%	4,006	4,288	71,302	1,222,637	5.62	0.33	6.01	0.35	35.16	30.33	0.08
Phoenix	BC	1,798	2,044	19,309	657,135	9.31	0.27	10.59	0.31	---	---	---
	10%	2,132	2,355	19,620	657,446	10.87	0.32	12.00	0.36	18.58	15.22	0.05
	25%	2,686	2,891	20,156	657,982	13.32	0.41	14.34	0.44	49.39	41.44	0.13

All values for year 2000

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

small when compared to either the total particulate dump (T) or to the particulate dump from combustion sources (CS) which characteristically emit particulates of a size range comparable to diesel exhaust matter. For the three regions examined, the effect of LDV dieselization at the 25-percent rate in the year 2000 is to cause an increase in the diesel particulate dump (D) of from 35 to 49 percent relative to the base case (1 percent LDV dieselization). The diesel dumps at the 25-percent rate represent contributions to the regional area total dumps of from 0.3 percent to 2.7 percent. The areawide total dumps are increased relative to the base case by 0.71 percent in Manhattan, 0.08 percent in St. Louis, and 0.13 percent in Phoenix. Effects in this range might apply to all urban areas nationwide.

Relative to the base case, the effect of 100-percent dieselization of taxis combined with 25-percent dieselization of passenger cars in Manhattan is to cause a 61 percent increase in the diesel dump. In this scenario the total vehicle (TV) dump represents a 3-percent contribution to the areawide total dump, an increase over the base case of about 1 percent.

From these results it is concluded that, considering particulates as a group-pollutant uniformly distributed over the regional area, dieselization would have a negligible effect on regional air quality. Local urban area conditions may have different ramifications, however, and these are discussed under local site effects.

S.3.1.2 Benzo(a)pyrene

Data on stationary source BaP emissions were not available for the regions examined nor could they be estimated with reasonable certainty. Effects due to the mobile source emission component are given in Table S-2, and may be summarized as follows. For the three regions examined, LDV dieselization at the 25-percent rate causes an increase in the mobile source BaP dump of from 40 to 53 percent based on a low estimate of diesel vehicle BaP emission rate, and from 62 to 86 percent based on a high estimate of diesel BaP emission rate. For Manhattan, 100-percent dieselization of taxis combined with 25-percent dieselization of passenger cars causes an increase in the mobile source BaP dump of from 68 percent (low estimate) to 109 percent (high

Table S-2. Areawide BaP Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Pounds Per Year				Percent Diesel Contribution (D/TV)		Percent Change From Base Case (BC)			
		Diesel (D)		Total Vehicles (TV)				Diesel (D)		Total Vehicles (TV)	
		Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.
Manhattan	BC	1.9	10.1	2.5	10.7	76.0	94.4	----	----	----	----
	10%	2.3	12.8	2.8	13.3	82.1	96.2	21.1	26.7	12.0	24.3
	25%	3.0	17.5	3.5	18.0	85.7	97.2	57.9	73.3	40.0	68.2
	25% PC + 100% Taxis	3.8	22.0	4.2	22.4	90.5	98.2	100.0	117.8	68.0	109.3
St. Louis	BC	13.8	73.8	18.2	78.2	75.8	94.4	----	----	----	----
	10%	17.0	92.6	21.1	96.7	80.6	95.8	23.2	25.5	15.9	23.7
	25%	22.1	123.5	25.7	127.1	86.0	97.2	60.1	67.3	41.2	62.5
Phoenix	BC	8.3	45.0	11.8	48.5	70.3	92.8	----	----	----	----
	10%	11.0	61.0	14.2	64.2	77.5	95.0	32.5	35.6	20.3	32.4
	25%	15.3	87.2	18.1	90.0	84.5	96.9	84.3	93.8	53.4	85.6

All values for year 2000

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

estimate) relative to the year 2000 base case. Excluding the Manhattan taxi scenario, the relative increases in BaP level do not vary widely among the regions examined.

There is no direct method for evaluating the effect of BaP on the environment. BaP has typically been measured and used in emissions research and air pollution monitoring as a general indicator of the presence of polynuclear aromatic hydrocarbons (PNA), but its value as an accurate index of total PNA emissions from a given source is questionable. Lacking the stationary source emissions for BaP, it is not possible to evaluate the relative contribution of dieselization to the specie dump.

S.3.1.3 Hydrocarbons

The areawide results for HC are shown in Table S-3 and may be summarized as follows. The effect of LDV dieselization is to decrease the HC dump. For the three regions examined, LDV dieselization at the 25-percent level decreases the total vehicle HC contribution by from 13.3 to 15.5 percent and decreases the regional area total dump by 9.3 percent for Manhattan, 3 percent for St. Louis, and 6 percent for Phoenix. This general trend is expected to hold for all urban regions nationwide, with the greatest improvements to be seen for those regions where motor vehicle emissions represent a large fraction of the total HC dump. An additional effect of dieselization is to reduce the dump (and required control) of HC evaporative emissions associated with gasoline marketing operatings. However, this diesel-related benefit is expected to become small as gasoline vapor recovery control measures are introduced nationwide.

These results indicate that the HC quality of the urban atmosphere will improve slightly with LDV dieselization. It must be noted, however, that the magnitude of the improvement that will be realized in fact is contingent upon the degree to which future diesel and gasoline vehicles match the emission levels and deterioration characteristics adopted as a base for this study.

Table S-3. Areawide HC Effects, Year 2000

Regional Area	Diesel-ization Rate	Dump, Tons Per Year			Percent Contribution		Percent Change from Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	579	4,299	6,251	9.3	68.8	---	---	---
	10%	677	4,086	6,038	11.2	67.7	16.9	-5.0	-3.4
	25%	839	3,718	5,670	14.8	65.6	44.9	-13.5	-9.3
St. Louis	BC	4,240	31,880	146,749	2.9	21.7	---	---	---
	10%	4,971	30,403	145,272	3.4	20.9	17.2	-4.6	-1.0
	25%	6,164	27,646	142,515	4.3	19.4	45.4	-13.3	-2.9
Phoenix	BC	2,577	28,986	74,089	3.5	39.1	---	---	---
	10%	3,238	27,202	72,305	4.5	37.6	25.6	-6.2	-2.4
	25%	4,302	24,479	69,582	6.2	35.2	66.9	-15.5	-6.1

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

S.3.1.4 Carbon Monoxide

The areawide effects of LDV dieselization on CO is to decrease the total vehicle and therefore the areawide total dump (see Table S-4). The reduction in total dump is substantial for all three regional areas: 12.9 percent for Manhattan, 6.6 percent for St. Louis, and 16.7 percent for Phoenix . While this trend is expected to hold for all urban areas nationwide, the magnitude of the reduction will vary with the relative importance of vehicle source contributions in each regional area. For areas such as Phoenix, with a relatively small industrial base, the effects will be substantial. For large industrial centers such as St. Louis, with a heavy CO contribution from industrial process sources, the effects will be smaller, though significant.

These results indicate that, on an areawide basis, the CO quality of the urban atmosphere will improve with LDV dieselization. As in the case of HC, the magnitude of the improvement that is actually realized will depend on the degree to which future diesel and gasoline vehicles match the emission levels and deterioration characteristics adopted for use in this study.

S.3.1.5 Oxides of Nitrogen

The environmental parameters for NO_x are shown in Table S-5. For all three regions, LDV dieselization reduces the NO_x dump relative to the base case. This occurs because the lifetime-average NO_x rate for diesel LDV's is lower than that for gasoline LDV's. The higher gasoline rate is a result of projected emission deterioration effects. Thus, each replacement of a gasoline vehicle by a diesel vehicle produces an incremental reduction in the regional area NO_x dump over the vehicle lifetime. At the 25-percent dieselization rate, the decrease in dump is 0.5 percent for Manhattan, 0.4 percent for St. Louis, and 4.1 percent for Phoenix. This trend is expected to hold for all urban areas nationwide. The improvement will be greatest in those areas where motor vehicles represent an important source of areawide NO_x emissions.

Table S-4. Areawide CO Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year			Percent Contribution		Percent Change from Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	5,419	35,651	44,439	12.2	80.2	---	---	---
	10%	5,810	33,475	42,264	13.7	79.2	7.2	-6.1	-4.9
	25%	6,457	29,899	38,687	16.7	77.3	19.2	-16.1	-12.9
St. Louis	BC	39,755	268,571	675,815	5.9	39.7	---	---	---
	10%	42,417	251,557	658,801	6.4	38.2	6.7	-6.3	-2.5
	25%	46,798	223,780	631,024	7.4	35.5	17.7	-16.7	-6.6
Phoenix	BC	24,063	242,387	264,359	9.1	91.7	---	---	---
	10%	26,320	227,409	249,381	10.6	91.2	9.4	-6.2	-5.7
	25%	30,043	198,357	220,329	13.6	90.0	24.9	-18.2	-16.7

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

Table S-5. Areawide NO_x Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year			Percent Contribution		Percent Change From Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	1,116	4,692	43,373	2.6	10.8	---	---	---
	10%	1,350	4,619	43,300	3.1	10.7	21.0	-1.6	-0.2
	25%	1,737	4,484	43,165	4.0	10.4	55.6	-4.4	-0.5
St. Louis	BC	8,171	34,784	490,778	1.7	7.1	---	---	---
	10%	9,830	34,093	490,087	2.0	7.0	20.3	-2.0	-0.1
	25%	12,551	33,012	489,006	2.6	6.8	53.6	-5.1	-0.4
Phoenix	BC	5,042	29,895	48,717	10.3	61.4	---	---	---
	10%	6,489	29,230	48,052	13.5	60.8	28.7	-2.2	-1.4
	25%	8,864	27,919	46,741	19.0	59.7	75.8	-6.6	-4.1

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

These results indicate that the NO_x quality of the urban atmosphere will improve slightly with LDV dieselization. Since the effect is small, minor deviations from the assumed conditions for gasoline and diesel vehicle emission levels and deterioration effects could negate, enhance, or reverse the trend indicated.

S.3.2 Local Site Effects

S.3.2.1 Particulates

S.3.2.1.1 Urban Freeway and Urban Street Canyon

The impact assessment for particulates in the urban freeway and urban street canyon parallels the assessment made for areawide effects in that it is based, in part, on conditions that would result if the sites examined were situated within each of the metropolitan regions studied. The method of approach was to establish representative values for the ambient levels of particulate concentration in these regions, and, using these as a base, to compute the absolute concentrations which would exist in each site for various dieselization scenarios. Effects were projected to the year 2000. These results were compared with the federal ambient air quality standard for TSP. Trends relative to the baseline case were assessed, and the significance of the concentration contribution due to LDV dieselization was evaluated.

The assessment uses the annual geometric mean concentration as a reference for evaluating air quality effects, since the maximum annual 24-hour concentration was either not reported or not given in a usable form for the regional areas studied. The results of this assessment are shown in Table S-6 and may be summarized as follows. The federal air quality standard of 75 $\mu g/m^3$ was found to be exceeded for every scenario case, including the baseline, a result due solely to the fact that the ambient backgrounds in the three regions were near, at, or above the standard level. This condition may be typical of many urban areas nationwide, so that dieselization to any degree tends to make the problem of meeting the TSP air quality requirement more difficult.

Table S-6. Urban Freeway Particulate Effects, Year 2000 (Annual Geometric Mean Concentrations)

		Median Position								100 Feet From Roadway Edge								300 Feet From Roadway Edge							
		Concentration, $\mu g/m^3$			%Contribution		% Change from BC			Concentration, $\mu g/m^3$			%Contribution		% Change from BC			Concentration, $\mu g/m^3$			%Contribution		% Change from BC		
Regional Area	Dieselization Rate	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T
Manhattan	BC	24.1	26.9	94	26	29	--	--	---	12.3	13.7	81	15	17	--	--	---	8.0	9.0	76	11	12	--	--	---
(Ambient = $67 \mu g/m^3$)	10%	27.6	30.1	97	28	31	14	12	3.4	14.1	15.4	82	17	19	14	12	2.1	9.2	10.1	77	12	13	14	12	1.4
	25%	33.2	35.4	102	32	35	38	32	9.0	16.9	18.1	85	20	22	38	32	5.4	11.0	11.8	79	14	15	38	32	3.7
	25% PC + 100% Taxis	38.6	40.9	108	36	38	61	53	15.0	19.7	20.8	88	22	24	61	53	8.8	12.9	13.6	81	16	17	61	53	6.0
St. Louis	BC	25.9	28.7	104	25	28	---	--	---	13.2	14.6	90	15	16	--	--	---	8.6	9.6	85	10	11	--	--	---
(Ambient = $75 \mu g/m^3$)	10%	29.4	31.9	107	28	30	13	11	3.1	15.1	16.3	91	17	18	13	11	1.9	9.8	10.7	86	11	12	13	11	1.3
	25%	35.2	37.4	112	31	33	35	30	8.4	17.9	19.1	94	19	20	35	30	5.0	11.7	12.5	88	13	14	35	30	3.4
Phoenix	BC	19.0	21.5	142	13	15	--	--	---	9.7	10.9	132	7.4	8.3	--	--	---	6.3	7.2	128	4.9	5.6	--	--	---
(Ambient = $121 \mu g/m^3$)	10%	22.6	24.7	146	16	17	19	15	2.2	11.6	12.6	134	8.7	9.4	19	15	1.3	7.5	8.3	129	5.8	6.4	19	15	0.8
	25%	28.1	30.3	151	19	20	49	41	6.2	14.3	15.5	136	10.5	11	49	41	3.5	9.3	10.1	131	7.1	7.7	49	41	2.3

All values for year 2000, Traffic rate = 188,000 veh/day

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

The concentration levels shown in the table are highest at the median position and decrease with distance from the roadway. The quantities must be viewed critically from the standpoint of their meaning relative to exposure effects impacting a significant fraction of the population. The annual geometric mean concentration is typically employed as a measure of long-term, general population impacts, whereas neither the median position nor the 100-ft position are characteristic of conditions meaningful in this context. The 300-ft position may be regarded as a long-term exposure site, since residences are frequently located at these distances, but only a minute fraction of all housing is so situated.

For the year 2000, diesel exhaust concentration contributions at the 25-percent dieselization rate range from a high at the roadway median position of from 28 to 35 $\mu g/m^3$ to a low of 9 to 12 $\mu g/m^3$ at 300 ft. The 300-ft results represent contributions to the federal air quality standard of from 12 to 16 percent.

Not indicated in Table S-6 is the fact that the HDV contribution to the diesel-total exhaust concentration is extremely high, ranging from 66 to 73 percent at the 25-percent LDV dieselization rate. Control of HDV particulate emissions to the level of 1.5 g/mi, compared to the assumed uncontrolled rate of 2.0 g/mi, would reduce the diesel exhaust concentration by 16 to 18 percent in the regions studied (all roadway positions).

Relative to the baseline case in the year 2000, LDV diselization at the 25-percent rate increases the diesel concentration contribution for all roadway positions by from 35 to 49 percent at the 300-ft position. These contributions have a minor impact on TSP, increasing the level by from 2.3 to 3.7 percent in the regions studied. Effects of this magnitude may be expected for urban areas nationwide.

The effect of 100-percent dieselization of taxicabs in Manhattan is to increase the diesel exhaust concentration by 17 percent relative to the 25-percent dieselization scenario. At the 300-ft roadway position, an exhaust concentration of about 13 $\mu g/m^3$ is produced. This compares to 8 $\mu g/m^3$ for the base case, an increase of 61 percent. The contribution to Manhattan TSP is 16 percent.

Following the procedure used for the urban freeway, absolute TSP concentration levels (annual geometric mean values) applicable to the three metropolitan regions studied were calculated for the street canyon traffic site. These and other parameters pertinent to the assessment of environmental effects in the street canyon site are shown in Table S-7. Values are provided for three street canyon heights: street level (6 ft), 30 ft, and 90-ft, representing locations near the street canyon building walls and therefore indicative of the quality of the atmosphere exposed to pedestrians and inducted for building ventilation.

TSP levels generally approaching or exceeding the federal standard of 75 $\mu g/m^3$ are indicated at all street canyon positions, a result due largely to the high ambient (non-vehicle-exhaust) concentration conditions in the metropolitan areas examined. This condition is expected to exist in many large metropolitan areas so that dieselization to any degree will add to the difficulty of attaining TSP air quality goals.

Diesel exhaust concentrations are much lower than those indicated for near-roadside positions in the urban freeway. The maximum levels occur at street level where concentrations ranging from 10 to 13 $\mu g/m^3$ (13 to 17 percent of the air quality standard) are seen at the 25-percent dieselization rate. Relative to the base case, LDV dieselization at 25 percent increases the diesel exhaust concentration by from 35 to 49 percent. These increases, though large, result in TSP increases of only 2.5 to 4 percent in the metropolitan areas examined. This effect is expected to hold for all urban areas nationwide.

The effect of 100-percent dieselization of taxicabs in Manhattan is to increase the diesel exhaust concentration by 17 percent relative to the 25-percent dieselization scenario and 61 percent relative to the base case (same values quoted for the urban freeway). The concentration is 14 $\mu g/m^3$ at street level, 11.3 $\mu g/m^3$ at 30 ft, and 6.8 $\mu g/m^3$ at 90 ft.

Table S-7. Street Canyon Particulate Effects, Year 2000
(Annual Geometric Mean Concentrations)

Regional Area	Dieseliza-tion Rate	Street Level (6 Ft)								30 Feet Above Street								90 Feet Above Street							
		Concentration, $\mu g/m^3$			% Contribution		% Change from BC			Concentration, $\mu g/m^3$			% Contribution		% Change from BC			Concentration, $\mu g/m^3$			% Contribution		% Change from BC		
		Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T
Manhattan (Ambient = $67 \mu g/m^3$)	BC	8.7	9.8	77	11	13	--	--	---	7.1	7.9	75	9.5	11	--	--	---	4.2	4.7	72	5.8	6.6	--	--	---
	10%	10.0	11.0	78	13	14	14	12	1.6	8.1	8.9	76	11	12	14	12	1.3	4.8	5.3	72	6.6	7.3	14	12	0.8
	25%	12.0	12.9	80	15	16	38	32	4.0	9.7	10.4	77	13	13	38	32	3.3	5.8	6.2	73	7.9	8.5	38	32	2.1
	25% PC + 100% Taxis	14.0	14.9	82	17	18	61	53	6.6	11.3	12.0	79	14	15	61	53	5.5	6.8	7.2	74	9.2	9.7	61	53	3.5
St. Louis (Ambient = $75 \mu g/m^3$)	BC	9.4	10.5	86	11	12	--	--	---	7.6	8.4	83	9	10	--	--	---	4.5	5.0	80	5.6	6.2	--	--	---
	10%	10.7	11.7	87	12	13	13	11	1.4	8.6	9.4	84	10	11	13	11	1.2	5.1	5.6	81	6.3	6.9	13	11	0.8
	25%	12.7	13.6	89	14	15	35	30	3.6	10.3	11.0	86	12	13	35	30	3.1	6.1	6.5	82	7.5	8.0	35	30	1.9
Phoenix (Ambient = $121 \mu g/m^3$)	BC	6.9	7.8	129	5.4	6.0	--	--	---	5.6	6.3	127	4.4	4.9	--	--	---	3.3	3.7	125	2.6	3.0	--	--	---
	10%	8.2	9.0	130	6.3	6.9	19	15	0.9	6.6	7.3	128	5.1	5.7	19	15	0.8	3.9	4.3	125	3.1	3.4	19	15	0.5
	25%	10.1	11.0	132	7.6	8.3	49	41	2.5	8.2	8.9	130	6.3	6.9	49	41	2.0	4.9	5.3	126	3.9	4.2	49	41	1.3

All values for year 2000, Traffic count = 936 veh/hr (24-hour average)

BC = Base Case (1% LDV/.2% LDT dieselization)

PC = Passenger Cars

S.3.2.1.2 Parking Garage

The analytic approach adopted for the treatment of the enclosed parking garage provides no basis for determining statistical means or maximums, nor for referencing exhaust concentrations to statistically-based ambient air concentrations. Moreover, the controlled, filtered atmosphere in a mechanically ventilated garage may be virtually independent of urban atmospheric conditions. For these reasons, the impacts of dieselization for the enclosed parking garage were examined only in terms of concentration changes relative to an unspecified ambient level in the incoming ventilation air.

In the year 2000, garage exhaust particulate concentrations at the 25-percent LDV dieselization rate are predicted to reach (best estimate) levels of 17 $\mu g/m^3$ diesel and 24 $\mu g/m^3$ total vehicle, during periods of off-peak garage activity. At rush hour conditions, when garage exit facilities become overloaded, concentration levels may temporarily peak at 400 $\mu g/m^3$ and levels over 100 $\mu g/m^3$ may persist for 30 minutes. While driver exposure to these atmospheres is probably less than 10 minutes per day, the high concentrations could be a matter of concern. A simple means of alleviating these conditions is to increase garage ventilation rates and/or to provide auxiliary ventilation equipment at critical garage sites such as exit ramps. It thus appears that particulate concentration effects in the enclosed parking garage should be amenable to control so that this traffic site would not constitute a barrier to LDV dieselization at any of the production rates considered.

S.3.2.2 Diesel Exhaust Odor

Odor analyses were performed for the urban freeway, the urban street canyon, and the enclosed parking garage. In each case, the diesel exhaust concentration for the conditions of a nominal average mix of diesel and gasoline vehicles corresponding to the highest dieselization rate considered in this study was found to produce no detectable odor effects. Recognizing, however, that odor levels may be strongly influenced by short-duration localized concentrations and that in any random event a high fraction of diesel vehicles may occur, the case for a 100-percent diesel population was investigated. This investigation yielded ambient D-numbers of 1.5 for the urban freeway, 2.6 for the street canyon, and 1.8 and 4.0 for off-peak actively and overload conditions, respectively, in the enclosed parking garage. At a D-number of 2.0, the lowest value ranked for odor response, 56 percent of the subjects tested evaluated the odor as unpleasant or worse. At a D-number of 3.0, 73 percent of the subjects tested evaluated the odor as unpleasant or worse.

From these results, it is concluded that for a nominally dieselized vehicle mix, diesel odor will not be a significant problem. However, localized high level exhaust concentrations are likely to occur, producing odor effects generally regarded as unpleasant or worse by a large segment of the public. The odor effects tend to be least severe for the urban freeway, somewhat higher for the street canyon, and highest for the parking garage under exit overload conditions. The garage problem, it may be noted, can be treated by providing adequate auxiliary ventilation for use during exit rush episodes.

S.4 POSSIBLE DIESELIZATION CONSTRAINTS AND ASSOCIATED ENERGY IMPACTS

The results of the environmental assessment were reviewed to determine if constraints on the possible extent of dieselization due to environmental factors were indicated. Uncertainties in the emission factors adopted for use in this study were examined, and the sensitivity of the environmental impact assessment to variation in NO_x and particulate emission rates was investigated. This review did not identify any constraints on dieselization due to environmental factors.

Recognizing that dieselization constraints may develop if LDV diesels are unable to meet the NO_x control requirement of 1.0 g/mi or the proposed particulate standard of 0.2 g/mi, an analysis was made of the loss in fuel savings which would occur if various elements of the LDV/LDT diesel sales market were barred from exploitation as a result of regulatory constraints on diesel vehicle emissions. Three cases for unconstrained LDV diesel sales were considered: (1) diesel sales fixed as a constant percentage of sales in all vehicle size classes, (2) diesel sales volume the same as in the first case but all sales in the full-size vehicle class, and (3) diesel sales volume the same as in the first case but all diesel sales in the subcompact class. Referenced to unconstrained diesel sales of 25 percent, the prohibition of LDV diesel sales would cause a loss of fuel savings in the year 2000 of 3.3 billion gal/yr on the basis of case 1 and 4 billion gal/yr on the basis of case 2. Case 3, in which all diesel sales are restricted to subcompact cars, would result in a loss of 1.7 billion gal/yr relative to the case for 25-percent unconstrained LDV sales in full-size cars. As a fraction of fuel consumed by an all-gasoline LDV fleet, these quantities are 5.0 percent, 6.1 percent, and 2.6 percent, respectively. The fuel savings foregone if LDT sales were prohibited would be 1.3 billion gal/yr in the year 2000, as referenced to unconstrained LDT sales of 25 percent. This is 5.0 percent of the fuel that would be consumed by an all-gasoline LDT fleet in the year 2000.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVE

Spurred by the passage of the Energy Policy and Conservation Act and the establishment of fuel economy standards for new production vehicles, the automobile industry has been investigating and, to some extent, implementing a number of technological improvements designed to reduce automobile fuel consumption. Among the drivetrain options under consideration for near-term mass production implementation is the diesel engine.

Future sales of diesel-powered passenger cars and other LDV's are projected to increase markedly. Faced with this potential, public and official government attention is being focused on possible impacts due to the widespread use of diesel engines in the vehicle fleet. At issue are the following:

- The emission characteristics of the diesel engine
- Physical and chemical composition of diesel engine particulate emissions
- Potential health impacts of diesel engine emissions
- Diesel odor and noise emissions
- LDV diesel fuel economy

With regard to environmental effects, the need to identify and better define the potential impacts of dieselization is supported by several recent DOT, EPA, and DOE studies, all of which cite diesel emissions in urban areas as a major unknown and as a potentially significant environmental influence. In recognition of this need, the present study undertakes the task of investigating the impacts on the urban atmosphere were a significant fraction of LDV's to be dieselized. This effort is regarded as a first step toward the resolution of unknowns and uncertainties surrounding the issue of dieselization effects on environment and health.

1.2 STUDY SCOPE

The study identifies and defines potential environmental impacts associated with the operation of diesel-powered vehicles in urban areas. The analytic effort focuses on diesel exhaust emission impacts upon air quality, with emphasis on particulates and odor. Impacts are projected over a 15-year period from 1985 to 2000. Environmental and regulatory factors that could constrain the introduction of LDV diesels are identified and the energy savings foregone are estimated.

The analysis of dieselization impacts is carried out on two levels; one concerned with air quality effects on an areawide (metropolitan) basis, the other dealing with effects in typically critical local urban traffic sites. The areawide analysis examines emission effects for HC, CO, NO_x, BaP, and particulates in three metropolitan regions: Manhattan, St. Louis, and Phoenix. The local site analysis examines emission effects for particulates and odor in three urban traffic facilities: the urban freeway, the urban street canyon, and the enclosed parking garage. The air quality analysis in this work is based on calculated pollutant concentration quantities.

1.3 ORGANIZATION OF REPORT

This report presents in sequence (1) the methodology employed in the analysis, (2) the calculated results for the regional pollutant dumps and local site concentrations, (3) the assessment of environmental impacts due to dieselization, and (4) the identification of dieselization constraints and associated losses in energy savings. The discussion of methodology is given in Section 2 for the areawide analysis and in Section 3 for the local site analysis. Computational results for these cases are presented in Sections 4.1 and 4.2, respectively. The findings of Section 4 are analyzed in terms of environmental impacts in Section 5. Section 6 discusses possible bounds on the extent of LDV dieselization, considering constraints imposed by environmental factors identified in Section 5 and constraints imposed by mandated levels for diesel vehicle exhaust emission control. Judgments are made as to the number and type of diesel vehicles impacted, and estimates of the resulting loss in energy savings are developed. A consolidated review of the study effort and its findings is provided in the Summary.

2. GENERAL URBAN AREA ANALYSIS

2.1 CASES STUDIED

The general urban area analysis portion of this study examines the impact of LDV dieselization with respect to areawide pollutant dump effects in the urban environment. Effects through the year 2000 are investigated, considering three possible rates of LDV dieselization in three selected metropolitan areas at four time points in the period of interest. A total of 36 major computational cases are investigated.

The set of urban areas selected for study was chosen so as to encompass a range of possible dump effects due to variations in vehicle miles of travel (VMT), the mix of gasoline/diesel highway vehicles, pollutant contributions from nontransportation sources, and other factors likely to determine worst-case environmental impacts due to dieselization. The urban areas selected were Manhattan (New York County), N.Y.; St. Louis, Missouri; and Phoenix, Arizona. Manhattan was chosen because of its uniquely high VMT contribution by taxicabs, which are prime candidates for dieselization; St. Louis because it is representative of large, highly industrialized urban cities with particulate and oxides of sulpher (SO_x) problems; and Phoenix because of its high truck-to-resident population ratio, representing cities where mobile sources make a major contribution to the total urban pollutant dump. Contact with the agencies responsible for air quality control in these areas was established for the purpose of obtaining region-specific data and supporting documentation on VMT projections, vehicle population characteristics, stationary source emissions, and other data. These contacts were the Arizona Department of Health Services/Bureau of Air Quality Control, the New York City Department of Air Resources, the New York State Department of Environmental Conservation, and the State of Missouri Division of Air Pollution Control. Wherever possible, these official sources were used as the basis for inputs to the computations. Where region-specific data were lacking, nationwide statistics were employed. Pertinent statistics for the areas selected are shown in Table 2-1.

Table 2-1. Metropolitan Areas Selected for Study

Parameter	Manhattan	St. Louis	Phoenix
Air Boundary	County Geographical Limits	AQCR	AQMA
County Jurisdictions Included	New York	Franklin, Jefferson, St. Charles, St. Louis, St. Louis City (Mo.), Bond, Clinton, Madison, Monroe, Randolph, St. Clair, Washington (Ill.)	Maricopa
Approximate Area, Sq. Mi.	21	6,470	1,700
Population	1,540,000[a]	2,470,000[a]	1,230,000[b]
Vehicles	231,000[a]	1,274,000[a]	707,000[b]

[a] 1970

[b] 1975

The pollutants considered in the general urban area analysis were HC, CO, NO_x, particulates, and BaP. Four time points were selected for examination: 1985, 1990, 2000, and a reference year (1975 or 1976, as used in the air quality implementation plans of the regional authority).

The term rate of dieselization, as used in this report, refers to the fraction of new vehicle production that is diesel-powered. With regard to possible rates of LDV dieselization, a brief review was made of various factors which could impact the number of diesel cars produced and sold in future years; e.g., consumer acceptance, future emission and fuel economy regulations, fuel availability, and state of development and capital requirements for alternate fuel economy improvement approaches. The results of this investigation are set forth in Appendix A. In brief, this analysis was unable to find a hard numerical basis for defining either a most likely or upper-limit level for LDV dieselization. At this time, with the issue of diesel emission control standards for NO_x and particulates yet to be resolved, the manufacturers are reluctant to make a large-scale commitment to the diesel engine. General Motors, however, has revealed that their contingency plan for meeting 1985 corporate average fuel economy requirements is to dieselize 25 percent of their new car production. In view of these uncertainties, and to ensure that all plausible cases were considered, this study attacked the problem parametrically and analyzed maximum LDV dieselization rates of 10 percent and 25 percent, in addition to a reference or base case in which dieselization was held constant at the 1978 level of one percent. The assumed time profiles for these scenarios are shown in Figure 2-1, indicating historical values to the year 1978, followed in the 10- and 25-percent cases by a roughly linear rise to maximum levels in the year 1985, with constant rate thereafter to the year 2000. In the base case, the one percent level was assumed to apply to all years after 1978.

In addition to the cases described above, a special scenario for the Manhattan region was investigated, in which 100 percent of the Manhattan taxi fleet was assumed to be dieselized by the year 1985. This case was examined in combination with a 25-percent dieselization rate applied to the Manhattan passenger car fleet.

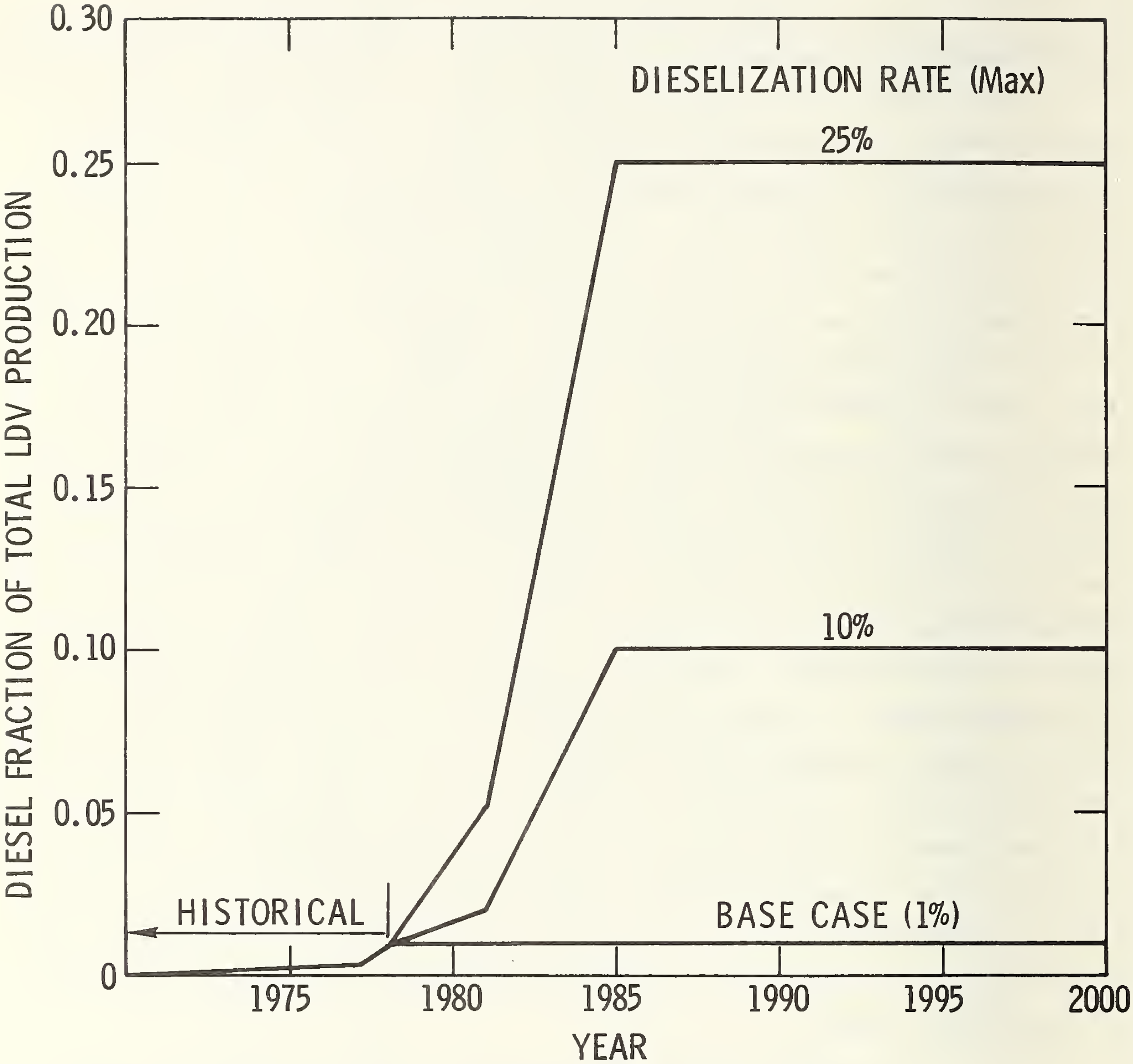

Figure 2-1. Selected Scenarios for the Diesel Fraction of LDV Production

2.2 METHODOLOGY AND DATA BASE

2.2.1 General Approach

A realistic assessment of the effects of LDV dieselization must consider pollutant contributions from a variety of sources, including emissions from other classes of vehicles and from stationary sources. In the present approach, the pollutant dump for each emission specie was first calculated for mobile sources, considering LDV, LDT, and HDV vehicles in two separate categories, diesel and gasoline powered. These emissions were then aggregated at several levels and finally the mobile source emissions were combined with stationary source emissions so as to establish the total specie dump for the region as a whole.

The calculation procedure used to determine the pollutant dump from vehicle sources generally follows the method outlined in EPA's Mobile Source Emission Factors document (Ref. 2-1). In this method, the dump is calculated as the product of a composite emission factor and an annual vehicle-miles-of-travel quantity, both values representing the vehicle class under consideration. For the purposes of the present study, the EPA relations are redefined in terms of an effective emission factor (travel-fraction-weighted), and considerations of vehicle speed, ambient temperatures, and fraction of cold/hot start operation are neglected. On this basis, the dump relationship for engine type e vehicles of a given vehicle class may be written

$$Dnpe = Enpe \times VMTn$$

where

Dnpe = dump of pollutant p from vehicles in the class with engine type e (diesel or gasoline) in calendar year n

Enpe = effective emission factor (g/mi) for the pollutant p for all in-use vehicles in the class with engine type e during calendar year n (travel-fraction-weighted)

VMTn = vehicle miles of travel for the vehicle class during calendar year n (region-specific)

The effective emission factor is developed separately for gasoline and diesel vehicles as a summation of mean emission rates and travel fractions using the following relations:

$$\text{Enpe} = \sum_{i=1}^{20} (\text{Cinpe})(\text{Mine})$$

$$\text{Cinpe} = \text{Aipe} + (\text{Bipe})(\text{Yine})$$

$$\text{Mine} = \frac{(\text{Rine})(\text{MPYine})(\text{Fine})}{\sum_{i} (\text{Rine})(\text{MPYine})}$$

where

Cinpe = FTP mean emission factor (g/mi) for pollutant p for ith model year vehicles with engine type e during calendar year n

Aipe = zero mileage exhaust emission rate (g/mi) of pollutant p for ith model year vehicles with engine type e

Bipe = emission deterioration rate, per 10,000 miles, of pollutant p for ith model year vehicles with engine type e

Yine = cumulative mileage of ith model year, engine type e vehicles in calendar year n, divided by 10,000

Rine = number of ith model year, engine type e vehicles in calendar year n

MPYine = annual mileage of ith model year, engine type e vehicles in calendar year n

Fine = class fraction of ith model year, engine type e vehicles in calender year n

As noted above, VMTn and Rine call for region-specific values; these data were obtained or evaluated from air quality implementation plans or studies in the metropolitan areas selected for investigation. Nationwide data or statistics were used for all other parameters, as well as in some cases for Rine where local information applicable to a given vehicle class or engine type were not available (see Section 2.2.2).

It may be seen that the method of approach is fundamentally based on regional VMT projections, fractionally weighted by mileage and emission factors which vary with vehicle type, model year, and age. By this method, there is no need to make an explicit calculation for the number of diesel vehicles in the regional fleets by projection year. However, such a calculation was performed, using estimated nationwide statistics, for the purpose of displaying the general population growth characteristics associated with the selected dieselization scenarios. The results of this calculation are given in Table 2-2. The diesel fraction for LDV's is plotted in Figure 2-2, showing that the composition of the in-use fleet approaches the selected values for maximum dieselization rate by the year 2000.

2.2.2 Mobile Source Emissions Inventory

2.2.2.1 LDT and HDV Projections

This analysis considers that the dieselization of LDV's would likely be accompanied by parallel developments in the LDT fleet. In addition, it accounts for a substantial growth in HDV dieselization. The assumptions made and procedures employed in developing the dieselization scenarios for these elements of the fleet are discussed in the following paragraphs.

2.2.2.1.1 Light-Duty Trucks

The designation LDT as used in this report refers to the EPA classification for vehicles in the gross vehicle weight rating (GVWR) range $\leq$ 8500 lb, which are designed primarily for the transportation of property (as opposed to passengers). It seemed reasonable to assume that the future production of diesel vehicles in this class should parallel the rates of growth proposed for passenger cars, since many LDT's are used in a dual role

Table 2-2. Nationwide Fleet Composition (Millions)

Percent Diesel Production	1975			1985			1990			2000		
	Gas	Diesel	Total	Gas	Diesel	Total	Gas	Diesel	Total	Gas	Diesel	Total
LDV												
Base Case[a]	97.6	0.1	97.7	116.9	0.9	117.8	128.0	1.3	129.3	155.3	1.6	156.9
10% Diesel	-	-	-	113.7	4.1	117.8	119.8	9.4	129.2	141.2	15.7	156.9
25% Diesel	-	-	-	108.3	9.5	117.8	105.6	23.7	129.3	117.7	39.2	156.9
LDT												
Base Case[b]	19.9	0.005	19.9	39.3	0.03	39.3	48.1	0.05	48.1	61.7	0.06	61.8
10% Diesel	-	-	-	38.1	1.2	39.3	45.0	3.1	48.1	55.8	6.0	61.8
25% Diesel	-	-	-	36.2	3.1	39.3	40.3	7.8	48.1	46.8	15.0	61.8
HDV												
Fleet	3.6	1.3	4.9	3.6	2.4	6.0	2.8	3.7	6.5	0.8	7.1	7.9
TOTAL FLEET[c]												
Base Case	121.1	1.4	122.5	159.8	3.3	163.1	178.9	5.0	183.9	217.8	8.8	226.6
10% Diesel	-	-	-	155.4	7.7	163.1	167.6	16.2	183.8	197.8	28.8	226.6
25% Diesel	-	-	-	148.1	15.0	163.1	148.7	35.2	183.9	165.3	61.3	226.6

[a]Base Case (1978): 1%

[b]Base Case (1977): .2%

[c]Slight discrepancies in totals due to rounding.

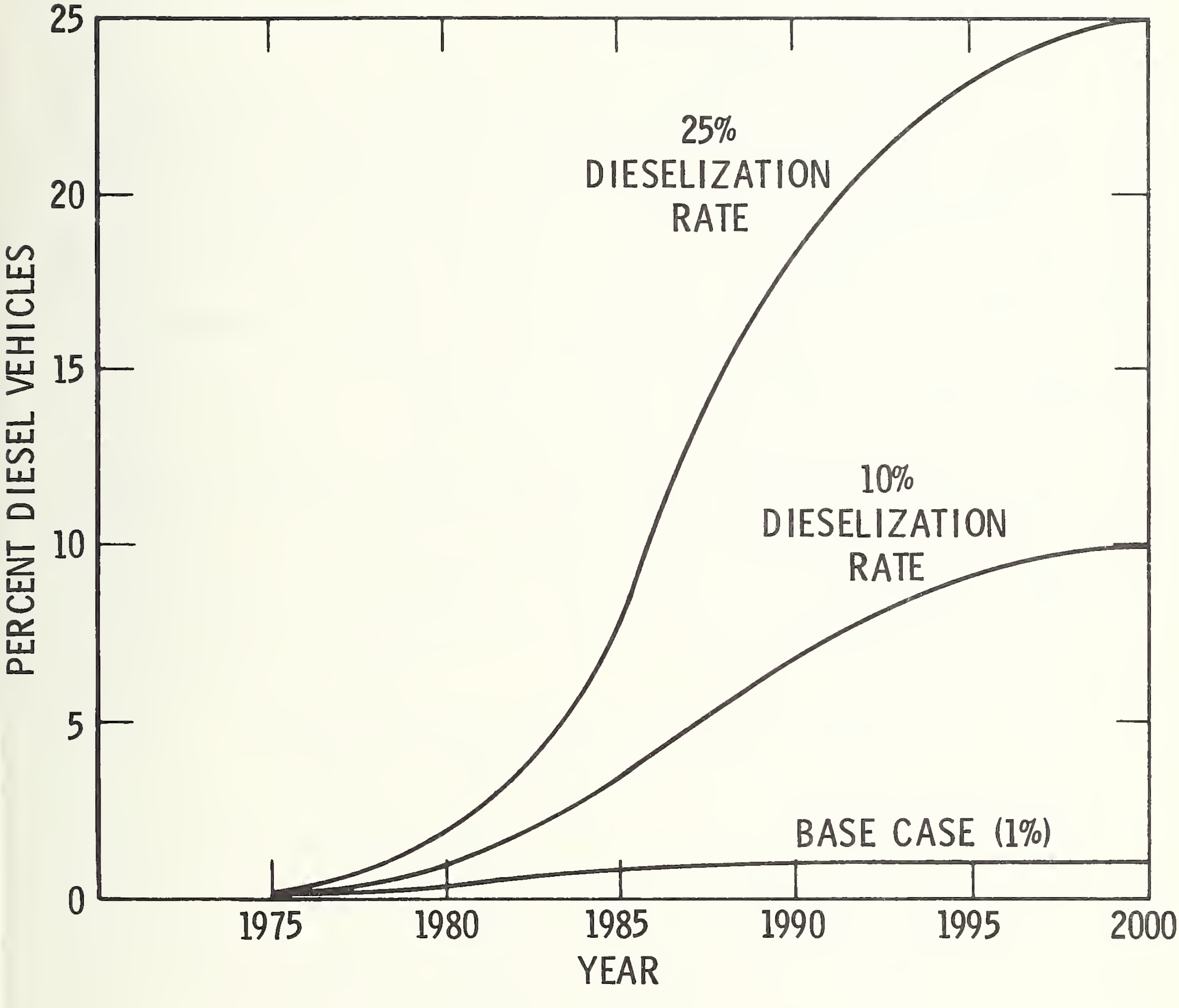

Figure 2-2. Diesel Fraction of the Light-Duty Vehicle Fleet (Nationwide)

that includes the transportation of passengers. Accordingly, the scenarios previously discussed for LDV dieselization, shown in Figure 2-1, were assumed to apply to LDT's, with a minor modification in the base or reference case. Here the projected sales of diesel LDT's were keyed to the sales fraction in model year 1977, the most recent historical data point available, or 0.2 percent (Ref. 2-2).

2.2.2.1.2 Heavy-Duty Vehicles

This class encompasses all road vehicles in the GVWR range above 8500 lb. In contrast to the parametric approach used in defining LDV and LDT dieselization, a single-valued projection was employed for the HDV class. The principal reason for adopting this approach was to keep the number of calculations within manageable limits. However, it may also be considered that the dollar value of energy savings due to dieselization of vehicles in this class makes the assumed growth in diesel population a much more likely event than in either of the other classes examined.

The Motor Vehicle Manufacturers Association (MVMA) classifies trucks into eight weight-related categories as follows:

MVMA Category	GVWR, lb
1	0 - 6000
2	6001 - 10,000
3	10,001 - 14,000
4	14,001 - 16,000
5	16,001 - 19,500
6	19,501 - 26,000
7	26,001 - 33,000
8	over 33,000

It may be seen that the HDV class as defined in this study encompasses MVMA truck categories 3 through 8, as well as a small fraction of MVMA truck category 2; i.e., the weight range from 8501 to 10,000 lb.

The factors needed to calculate the diesel fraction of heavy-duty vehicles projected for the future are (1) vehicle sales, and (2) diesel sales fraction by weight class. In Reference 2-3, these factors were projected to the year 2000 for high, moderate, and low expectations of economic growth nationwide. The moderate projections are utilized in the present study because they are reported to represent (1) best estimate values for vehicle sales, and (2) most likely values for the diesel fraction applicable to truck Categories 6 through 8 which comprise the bulk of the heavy-duty vehicle fleet. With regard to the treatment of Category 2 vehicles in the HDV weight range, Reference 2-4 indicates that such vehicles represent about 2.5 percent of total Category 2 vehicle sales. This figure was applied as a constant to the sales projections for Category 2 vehicles in order to isolate the HDV fraction. The resulting sales and diesel fraction projections as derived from Reference 2-3 are shown in Figures 2-3 and 2-4, respectively. In Figure 2-5, these factors are combined by weight class and summed to show the diesel fraction of total HDV truck production by model year. This characteristic was used as the basis for projecting the diesel fraction of in-use HDV's for all three metropolitan regions.

2.2.2.2 Vehicle Mileage and Survivability Characteristics

In addition to the diesel fraction, the calculation of composite emission factors requires a definition of (1) vehicle annual mileage, (2) vehicle cumulative mileage, and (3) fleet composition as a function of vehicle age. The data used in this report were based, wherever possible, on region-specific information obtained from air quality implementation plans or studies. Lacking these, nationwide statistics given in EPA's Mobile Source Emission Factors (MSEF) document (Ref. 2-1) were used. The data employed, along with their sources, are given in Tables 2-3 through 2-6.

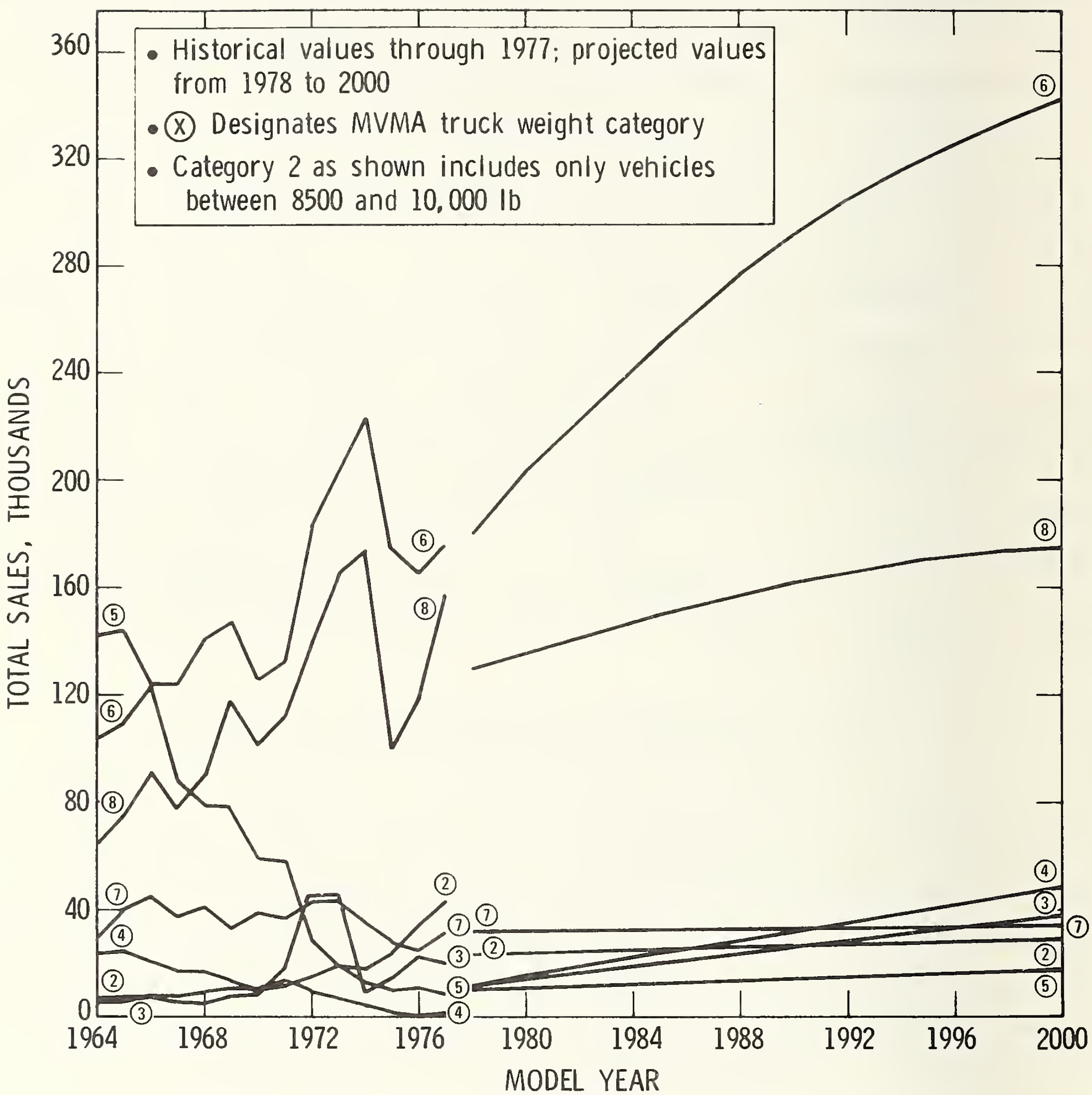

Figure 2-3. Projected HDV Sales by Truck Category (Reference 2-3)

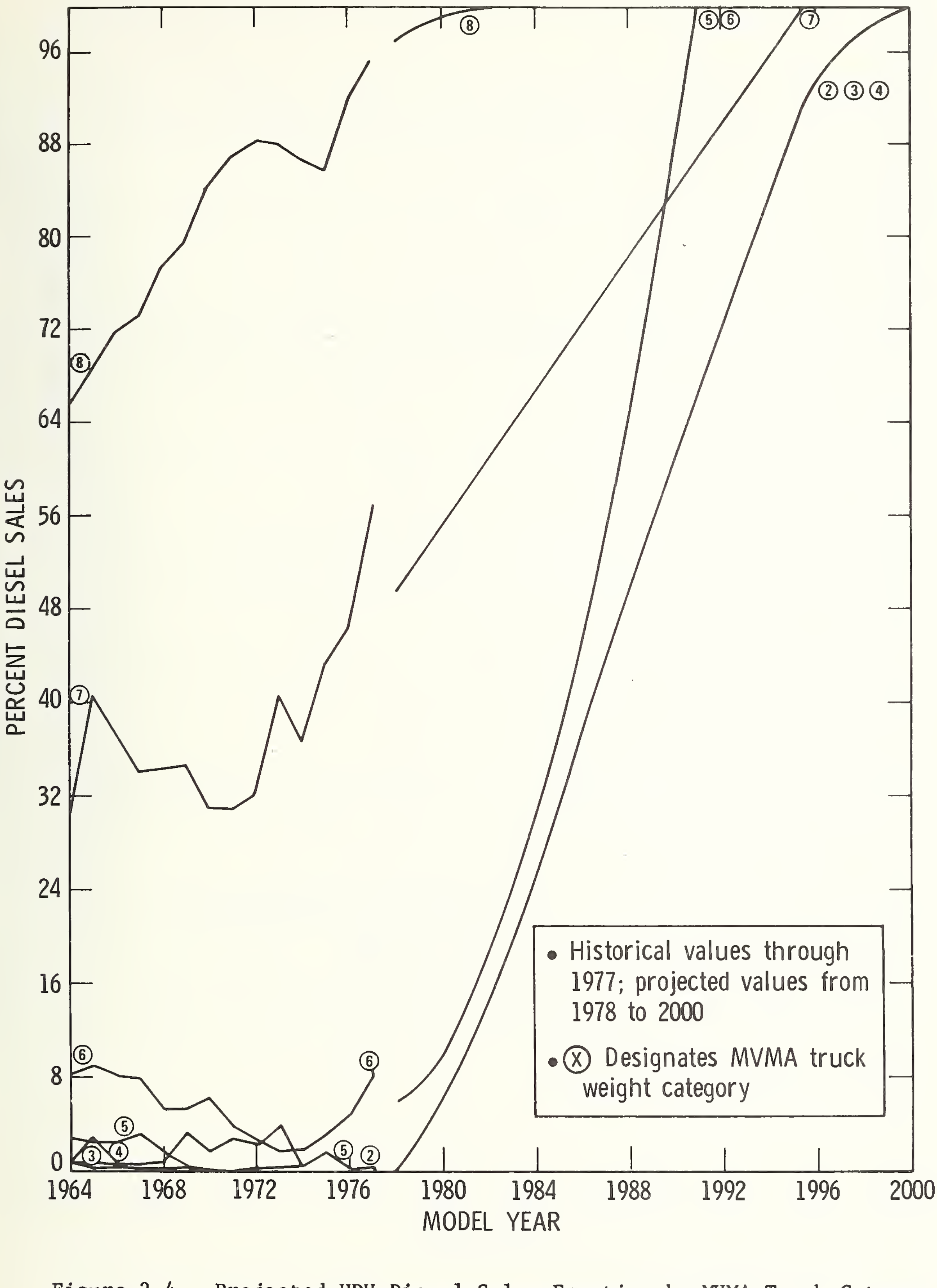

Figure 2-4. Projected HDV Diesel Sales Fraction by MVMA Truck Category (Reference 2-3)

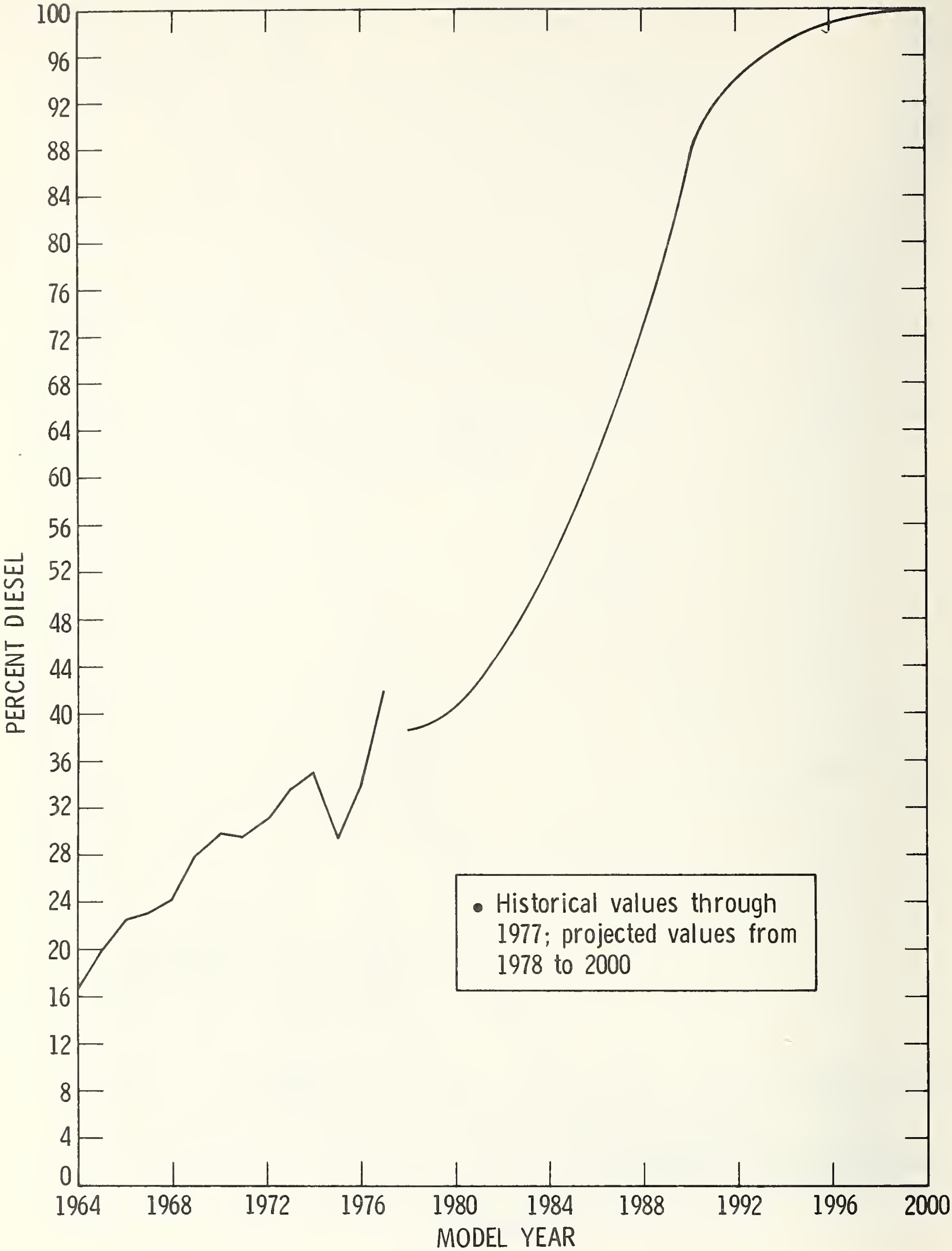

Figure 2-5. Characteristic Used for Diesel Fraction of Total HDV Truck Production

Table 2-3. Annual Mileage by Vehicle Age -- All Regions

Vehicle Age, Yrs.	LDV	LDT		HDV	
		<6000#	6001-8500#	Gas	Diesel
1	15900	15900	15700	19000	73600
2	15000	15000	15700	19000	73600
3	14000	14000	14100	17900	69900
4	13100	13100	12600	16500	63300
5	12200	12200	11300	15000	56600
6	11300	11300	10200	13500	50000
7	10300	10300	9400	12000	45600
8	9400	9400	8600	10600	41200
9	8500	8500	8000	9500	38200
10	7600	7600	7500	8600	36000
11	6700	6700	7100	7800	34600
12	6600	6600	6600	7000	33800
13	6200	6200	6300	6300	33100
14	5900	5900	6000	5900	32400
15	5500	5500	5500	5300	30900
16	5100	5100	5200	4900	28700
17	5000	5000	5000	4700	25700
18	4700	4700	4700	4600	21300
19	4400	4400	4400	4400	18400
20	4400	4400	4100	4200	15400

Nationwide Statistics; Source: Reference 2-1

Table 2-4. Fraction of Vehicles in Use by Age -- Manhattan and St. Louis

Vehicle Age, Yrs.	LDV		LDT[a]		HDV[a]	
	Man. (b)	St. Louis (c)	<6000#	6001-8500#	Gas	Diesel
1	0.1310	0.1010	0.061	0.037	0.037	0.077
2	0.1648	0.1270	0.095	0.070	0.070	0.135
3	0.1225	0.1030	0.094	0.078	0.078	0.134
4	0.0963	0.0980	0.103	0.086	0.086	0.131
5	0.0870	0.1070	0.083	0.075	0.075	0.099
6	0.0883	0.0910	0.076	0.075	0.075	0.090
7	0.0801	0.0820	0.076	0.075	0.075	0.082
8	0.0611	0.0780	0.063	0.068	0.068	0.062
9	0.0522	0.0610	0.054	0.059	0.059	0.045
10	0.0468	0.0480	0.043	0.053	0.053	0.033
11	0.0274	0.0340	0.036	0.044	0.044	0.025
12	0.0180	0.0190	0.024	0.032	0.032	0.015
13	0.0059	0.0150	0.030	0.038	0.038	0.013
14	0.0046	0.0105	0.028	0.036	0.036	0.011
15	0.0029	0.0068	0.026	0.034	0.034	0.010
16	0.0020	0.0045	0.024	0.032	0.032	0.008
17	0.0016	0.0038	0.022	0.030	0.030	0.007
18	0.0016	0.0038	0.020	0.028	0.028	0.006
19	0.0016	0.0038	0.018	0.026	0.026	0.005
20	0.0013	0.0030	0.016	0.024	0.024	0.004

(a) Nationwide Statistics, Reference 2-1; (b) Reference 2-5; (c) Reference 2-6.

Table 2-5. Fraction of Vehicles in Use by Age -- Phoenix

Vehicle Age, Yrs.	LDV	LDT		HDV	
		<6000#	6001-8500#	Gas	Diesel
1	0.066	0.063	0.063	0.059	0.058
2	0.089	0.096	0.096	0.097	0.105
3	0.111	0.122	0.122	0.110	0.153
4	0.105	0.106	0.106	0.148	0.115
5	0.084	0.070	0.070	0.063	0.095
6	0.084	0.072	0.072	0.069	0.074
7	0.085	0.071	0.071	0.071	0.075
8	0.071	0.052	0.052	0.043	0.054
9	0.062	0.047	0.047	0.042	0.057
10	0.059	0.046	0.046	0.043	0.046
11	0.052	0.042	0.042	0.033	0.030
12	0.038	0.039	0.039	0.031	0.030
13	0.026	0.028	0.028	0.029	0.022
14	0.020	0.026	0.026	0.028	0.018
15	0.013	0.025	0.025	0.026	0.017
16	0.008	0.023	0.023	0.025	0.013
17	0.007	0.021	0.021	0.023	0.012
18	0.007	0.019	0.019	0.022	0.010
19	0.007	0.017	0.017	0.020	0.008
20	0.006	0.015	0.015	0.018	0.007

Source: Reference 2-7

Table 2-6. Cumulative Mileage by Vehicle Age -- All Regions

Vehicle Age, Yrs	LDV	LDT		HDV	
		6000#	6001-8500#	Gas	Diesel
1	5962	5962	5888	4750	18400
2	19622	19622	19625	19000	73600
3	34369	34369	34875	37862	146738
4	48147	48147	48603	55725	216275
5	61022	61022	60884	72212	279562
6	72997	72997	71916	87212	336175
7	84044	84044	81925	100712	386450
8	94122	94122	91125	112725	432050
9	103297	103297	99581	123362	473425
10	111571	111571	107459	132887	511725
11	118946	118946	114862	141500	547825
12	125646	125646	121834	149300	582500
13	132137	132137	128365	156312	616312
14	138265	138265	134590	162650	649412
15	144062	144062	140459	168525	681712
16	149462	149462	145890	173850	712525
17	154546	154546	151043	178775	741125
18	159465	159465	155965	183487	766650
19	164090	164090	160590	188075	788137
20	168499	168499	164915	192474	806525

Nationwide Statistics; Source: Reference 2-1.

A point should be made concerning the HDV mileage data, which are categorized by engine type; i.e., gasoline or diesel. In treating the diesel growth for the heavy-duty fleet, it was not possible to track the effects of the changing diesel-to-gasoline fractions for individual categories of HDV trucks. The required data were not available and, moreover, the process would have increased the complexity of the calculations by an order of magnitude. Instead, this class of vehicle was treated as a group, with the assumption that the age/mileage profile and vehicle-in-use fraction would remain unaltered as the fleet became more dieselized. This assumption is consistent with the projections given in Figures 2-3 and 2-4, which indicate that about 70 percent of the total growth in diesel HDV's is accounted for by vehicles in truck categories 6 and 8, largely representing the heavier commercial vehicles with duty cycles and lifetime characteristics similar to the existing diesel fleet.

2.2.2.3 VMT Projections

Projections of VMT through the year 2000 as supplied by the regional authority in the areas selected for study are given in Table 2-7. The following characteristics may be noted. Manhattan expects a zero growth in VMT (Ref. 2-8), St. Louis projects a moderate growth in VMT, while Phoenix plans for a substantial growth in VMT -- on the order of 100 percent by the year 2000 (Ref. 2-7).

2.2.2.4 Emission Rates

As noted earlier, the mobile source emissions inventory is based on region-specific VMT and composite emission factors for each class of gasoline and diesel powered-vehicle (LDV, LDT, and HDV). Pollutant-specific composite emission factors are developed using the method recommended by EPA in Reference 2-1 (Mobile Source Emission Factors) for each of the regions of interest. In this method, a fleet-composite pollutant emission factor is defined for each pollutant, for each vehicle class, for a given calendar year, as: the sum over all model years of the product of (1) the new engine emission rate plus the deterioration rate and (2) the fraction of total annual travel applicable to a given model year.

Table 2-7. Projected Vehicle Miles of Travel (10^6 VMT Per Day)

City	Projection Year				References
	1975	1985	1990	2000	
<u>Manhattan</u>					
LDV	6.11	6.11	6.11	6.11	2-8, 2-5
LDT	0.23	0.23	0.23	0.23	
HDV	0.55	0.55	0.55	0.55	
<u>St. Louis</u>					
LDV	29.78	32.28	33.67	36.99	2-6, 2-9, 2-10
LDT	4.67	5.06	5.28	5.80	
HDV	3.25	3.52	3.67	4.04	
<u>Phoenix</u>					
LDV	13.46	20.01	23.07	29.19	2-7
LDT	3.35	4.98	5.74	7.27	
HDV	1.20	1.63	1.90	2.44	

Tables 2-8 through 2-15 delineate the values that were used for new engine emission rate and for emission deterioration rate. The values shown for HC, CO, and NO_x exhaust emissions and HC evaporative and crankcase emissions were largely taken from Mobile Source Emission Factors (Ref. 2-1) in the case of gasoline vehicles and diesel heavy-duty vehicles (HDVD's), and from AP-42 (Ref. 2-11) and other sources in the case of diesel light-duty vehicles (LDVD's) and diesel light-duty trucks (LDTD's). The LDV values, it should be noted, are based in part on EPA's Emission Factor Program, which attempts to characterize the emissions of vehicles in their actual in-use condition. Data generated from surveillance testing of in-use vehicles in a number of cities (including St. Louis and Phoenix) are used for this purpose. Therefore, the emission effects indicated in the tables do not necessarily conform to new vehicle certification requirements.

Exhaust particulate emissions for gasoline-powered vehicles are based on data supplied by EPA to PEDCo (Ref. 2-12). The emission rates shown for exhaust particulates in LDVD's were obtained as follows: Values shown for 1981+ model years were based on proposed EPA standards which were not yet promulgated or precisely defined at the time this study was executed. These proposed standards were 0.6 g/mi beginning in 1981 and 0.2-0.3 g/mi beginning in the 1983 to 1985 period (Ref. 2-13). This study adopted a value of 0.6 g/mi for the 1981 to 1984 period and a value of 0.25 g/mi for 1985 and subsequent model years. The impact of a 0.2 g/mi standard starting in 1983, as promulgated in a recent notice of proposed rulemaking, is discussed in Section 5. The proposed standard of 0.6 g/mi starting in 1981 is typical of values reported in the literature for existing (uncontrolled) LDVD's and hence was also used as the exhaust particulate emission factor for the pre-1981 model years.

For HDVD's, the emission rate for exhaust particulates was taken as 2.0 g/mi, which is the value used by PEDCo (Ref. 2-12). Discussions with EPA (Ref. 2-15) indicated that no particulate standard for HDVD's had yet been proposed and that the 2.0 g/mi value was a reasonable nominal value for the uncontrolled emission rate of such vehicles.

Table 2-8. Vehicle Emission Factors -- Gasoline LDV

Pollutant	Year(s)	Applicable Standard(1)	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi(2)	Source
Exhaust HC	Pre-1968	Uncontrolled	4.45	0.58Y	MSEF(3)
	1968-1974	3.40(4)	2.43	0.53Y	MSEF
	1975-1979	1.50	1.13	0.23Y	MSEF
	1980+	0.41	0.13	0.23Y	MSEF
Evaporative and Crankcase HC	Pre-1963	(5, 6)	6.63	0.00Y	MSEF
	1963-1967	(5, 6)	3.33	0.00Y	MSEF
	1968-1970	(5, 6)	2.53	0.00Y	MSEF
	1971-1977	(5, 6)	1.76	0.00Y	MSEF
	1978-1979	(5, 6)	0.60	0.00Y	MSEF
	1980+	(5, 6)	0.15	0.00Y	MSEF
Exhaust CO	Pre-1968	Uncontrolled	68.30	3.06Y	MSEF
	1968-1974	39.0(4)	31.14	6.15Y	MSEF
	1975-1979	15.0	18.60	2.80Y	MSEF
	1980	7.0	3.00	2.30Y	MSEF
	1981+	3.4(7)	1.40	2.00Y	MSEF
Exhaust NO_x	Pre-1968	Uncontrolled	3.58	0.00Y	MSEF
	1968-1972	Uncontrolled	4.43	0.00Y	MSEF
	1973-1974	3.0	2.98	0.00Y	MSEF
	1975-1976	3.1	2.42	0.08Y	MSEF
	1977-1980	2.0	1.50	0.16Y	MSEF
	1981+	1.0	0.29	0.22Y	MSEF
Exhaust Particulates	Catalyst	Uncontrolled	0.006	0.00Y	PEDCo/EPA
	Catalyst, EA(8)	Uncontrolled	0.015	0.00Y	PEDCo/EPA
	Non-Cat., LF(9)	Uncontrolled	0.25	0.00Y	PEDCo/EPA
	Non-Cat., UF(10)	Uncontrolled	0.002	0.00Y	PEDCo/EPA
Exhaust BaP	Catalyst	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Catalyst, EA(8)	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., LF(9)	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., UF(10)	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.00Y	AP-42

(1) 49 states; g/mi unless otherwise indicated.

(2) Y = cumulative mileage/10,000.

(3) Mobile Source Emission Factors (Ref. 2-1).

(4) 1972-1974; earlier standards based on different test procedure.

(5) No evaporative standards prior to 1971; increasingly stringent standards thereafter.

(6) No crankcase standards prior to 1968; zero thereafter.

(7) Possible waiver to 7 g/mi for up to 2 years.

(8) Excess air.

(9) Leaded fuel.

(10) Unleaded fuel.

Table 2-9. Vehicle Emission Factors -- Diesel LDV

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1968	Uncontrolled	0.5	0.0	AP-42
	1968-1974	Uncontrolled	0.5	0.0	AP-42
	1975-1979	1.5	0.6	0.0	Cert. Data
	1980+	0.41	0.41	0.0	Statutory
Evaporative HC	All	Uncontrolled	0.0	0.0	
Exhaust CO	Pre-1968	Uncontrolled	1.7	0.0	AP-42
	1968-1974	Uncontrolled	1.7	0.0	AP-42
	1975-1979	15.0	1.7	0.0	AP-42
	1980	7.0	1.7	0.0	AP-42
	1981+	3.4[3]	1.7	0.0	AP-42
Exhaust NO_x	Pre-1968	Uncontrolled	1.6	0.0	AP-42
	1968-1972	Uncontrolled	1.6	0.0	AP-42
	1973-1974	Uncontrolled	1.6	0.0	AP-42
	1975-1976	3.1	1.5	0.0	Cert. Data
	1977-1980	2.0	1.5	0.0	Cert. Data
	1981-1984	1.0[4]	1.5[5]	0.0	Statutory
	1985+	1.0	1.0	0.0	Statutory
Exhaust Particulates	Pre-1981	Uncontrolled	0.6	0.0	
	1981-1984	0.6	0.6	0.0	(6)
	1985+[6]	0.2-0.3[7]	0.25	0.0	(6)
Exhaust BaP	All	Uncontrolled	1.0-6.0 μg/mi	0.0	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.0	AP-42

(1) 49 states; g/mi unless otherwise indicated.
(2) Deterioration rate taken to be 0 for diesels.
(3) Waiver to 7 g/mi can be petitioned for up to 2 years.
(4) Waiver to 1.5 g/mi can be petitioned for up to 4 years.
(5) Assumes waiver to 1.5 g/mi will be granted for diesels.
(6) Assumed.
(7) Proposed particulate standards for light-duty diesels: starting 1981, 0.6 g/mi; starting 1983-1985, 0.2-0.3 g/mi (Ref. 2-13).

Table 2-10. Vehicle Emission Factors -- Gasoline LDT, 0-6000#

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1968	Uncontrolled	4.45	0.58Y	MSEF[3]
	1968-1974	3.4[4]	2.43	0.53Y	MSEF
	1975-1978	2.0	1.11	0.41Y	MSEF
	1979-1982	1.7	0.94	0.41Y	MSEF
	1983+	0.99[5]	0.31	0.23Y	MSEF
Evaporative and Crankcase HC	Pre-1963	(6,7)	6.63	0.00Y	MSEF
	1963-1967	(6,7)	3.33	0.00Y	MSEF
	1968-1970	(6,7)	2.53	0.00Y	MSEF
	1971-1977	(6,7)	1.76	0.00Y	MSEF
	1978-1979	(6,7)	0.60	0.00Y	MSEF
	1980+	(6,7)	0.15	0.00Y	MSEF
Exhaust CO	Pre-1968	Uncontrolled	68.30	3.06Y	MSEF
	1968-1974	39.0[4]	31.14	6.15Y	MSEF
	1975-1978	20.0	16.10	5.34Y	MSEF
	1979-1982	18.0	14.50	5.34Y	MSEF
	1983+	9.4[5]	3.87	2.00Y	MSEF
Exhaust NO_x	Pre-1968	Uncontrolled	3.58	0.00Y	MSEF
	1968-1972	Uncontrolled	4.43	0.00Y	MSEF
	1973-1974	3.0	2.98	0.00Y	MSEF
	1975-1978	3.1	2.45	0.00Y	MSEF
	1979-1984	2.3	1.73	0.11Y	MSEF
	1985+	1.4[5]	0.41	0.22Y	MSEF
Exhaust Particulates	Catalyst	Uncontrolled	0.006	0.00Y	PEDCo/EPA
	Catalyst, EA[8]	Uncontrolled	0.015	0.00Y	PEDCo/EPA
	Non-Cat., LF[9]	Uncontrolled	0.25	0.00Y	PEDCo/EPA
	Non-Cat., UF[10]	Uncontrolled	0.002	0.00Y	PEDCo/EPA
Exhaust BaP	Catalyst	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Catalyst, EA[8]	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., LF[9]	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., UF[10]	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.00Y	AP-42

(1) 49 states; g/mi unless otherwise indicated.
(2) Y = cumulative mileage/10,000.
(3) Mobile Source Emission Factors (Ref. 2-1).
(4) 1972-1974; earlier standards based on different test procedure.
(5) Predicted standard, MSEF.
(6) No evaporative standards prior to 1971; increasingly stringent standards thereafter.
(7) No crankcase standards prior to 1962; zero thereafter.
(8) Excess air.
(9) Leaded fuel.
(10) Unleaded fuel.

Table 2-11. Vehicle Emission Factors -- Gasoline LDT, 6001-8500#

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1970	Uncontrolled	5.99	0.58Y	MSEF[3]
	1970-1973	275 ppm	2.90	0.53Y	MSEF
	1974-1978	(4)	2.90	0.53Y	MSEF
	1979-1982	1.7	0.94	0.41Y	MSEF
	1983+	0.99[5]	0.31	0.23Y	MSEF
Evaporative and Crankcase HC	Pre-1968	(6,7)	7.70	0.00Y	MSEF
	1968-1978	(6,7)	2.53	0.00Y	MSEF
	1979	(6,7)	0.60	0.00Y	MSEF
	1980+	(6,7)	0.15	0.00Y	MSEF
Exhaust CO	Pre-1970	Uncontrolled	78.70	3.06Y	MSEF
	1970-1973	1.5%	32.40	6.15Y	MSEF
	1974-1978	40 g/bhp-hr	32.40	6.15Y	MSEF
	1979-1982	18	14.50	5.34Y	MSEF
	1983+	9.4[5]	3.87	2.00Y	MSEF
Exhaust NO_x	Pre-1970	Uncontrolled	6.49	0.00Y	MSEF
	1970-1973	Uncontrolled	5.04	0.00Y	MSEF
	1974-1978	(4)	5.04	0.00Y	MSEF
	1979-1984	2.3	1.73	0.11Y	MSEF
	1985+	1.4[5]	0.41	0.22Y	MSEF
Exhaust Particulates	Catalyst	Uncontrolled	0.006	0.00Y	PEDCo/EPA
	Catalyst, EA[8]	Uncontrolled	0.015	0.00Y	PEDCo/EPA
	Non-Cat., LF[9]	Uncontrolled	0.25	0.00Y	PEDCo/EPA
	Non-Cat., UF[10]	Uncontrolled	0.002	0.00Y	PEDCo/EPA
Exhaust BaP	Catalyst	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Catalyst, EA[8]	Uncontrolled	0.10 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., LF[9]	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., UF[10]	Uncontrolled	1.00 μg/mi	0.00Y	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.00Y	AP-42

(1)49 states; g/mi unless otherwise indicated.
(2)Y = cumulative mileage/10,000.
(3)Mobile Source Emission Factors (Ref. 2-1).
(4)HC + NO_x = 16 g/bhp-hr.
(5)Predicted standard, MSEF.
(6)No evaporative standard prior to 1979; LDVG evaporative standard thereafter.
(7)No crankcase standard prior to 1970; zero thereafter.
(8)Excess air.
(9)Leaded fuel.
(10)Unleaded fuel.

Table 2-12. Vehicle Emission Factors -- Diesel LDT, 0-6000#

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1968	Uncontrolled	0.8	0.0	(3)
	1968-1974	Uncontrolled	0.8	0.0	(3)
	1975-1978	2.0	0.8	0.0	(3)
	1979-1982	1.7	0.8	0.0	(3)
	1983+	0.99[4]	0.8	0.0	(3)
Evaporative HC	All	Uncontrolled	0.0	0.0	
Exhaust CO	Pre-1968	Uncontrolled	1.7	0.0	(3)
	1968-1974	Uncontrolled	1.7	0.0	(3)
	1975-1978	20.0	1.7	0.0	(3)
	1979-1982	18.0	1.7	0.0	(3)
	1983+	9.4[4]	1.7	0.0	(3)
Exhaust NO_x	Pre-1968	Uncontrolled	1.6	0.0	(3)
	1968-1972	Uncontrolled	1.6	0.0	(3)
	1973-1974	Uncontrolled	1.6	0.0	(3)
	1975-1978	3.1	1.6	0.0	(3)
	1979-1984	2.3	1.6	0.0	(3)
	1985+	1.4[4]	1.4	0.0	(5)
Exhaust Particulates	Pre-1981	Uncontrolled	0.6	0.0	(5)
	1981-1984[5]	0.6[6]	0.6	0.0	(5)
	1985+[5]	0.2 - 0.3[6]	0.25	0.0	(5)
Exhaust BaP	All	Uncontrolled	1.0-6.0 μg/mi	0.0	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.0	AP-42

(1) G/mi unless otherwise indicated.

(2) Deterioration rate taken to be 0 for diesels.

(3) Certification data on 1978 GM pickup truck (Ref. 2-14).

(4) Predicted standard per MSEF.

(5) Assumed.

(6) Proposed particulate standards for light duty diesels: starting 1981, 0.6 g/mi; starting 1983-1985, 0.2 - 0.3 g/mi. (Ref. 2-13).

Table 2-13. Vehicle Emission Factors -- Diesel LDT, 6001-8500#

Pollutant	Year(s)	Applicable Standard(1)	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi(2)	Source
Exhaust HC	Pre-1970	Uncontrolled	0.8	0.0	(3)
	1970-1973	Uncontrolled	0.8	0.0	(3)
	1974-1978	(4)	0.8	0.0	(3)
	1979-1982	1.7	0.8	0.0	(3)
	1983+	0.99(5)	0.8	0.0	(3)
Evaporative HC	All	Uncontrolled	0.0	0.0	(6)
Exhaust CO	Pre-1970	Uncontrolled	1.7	0.0	
	1970-1973	Uncontrolled	1.7	0.0	(3)
	1974-1978	40 g/bhp-hr	1.7	0.0	(3)
	1979-1982	18.0	1.7	0.0	(3)
	1983+	9.4(5)	1.7	0.0	(3)
Exhaust NO_x	Pre-1974	Uncontrolled	1.8	0.0	(6)
	1974-1978	(4)	1.8	0.0	(3)
	1979-1982	2.3	1.8	0.0	(3)
	1983-1984	2.3	1.8	0.0	(3)
	1985+	1.4(5)	1.4	0.0	(6)
Exhaust Particulates	Pre-1981	Uncontrolled	0.80	0.0	SWRI
	1981-1984(6)	0.6(7)	0.60	0.0	SWRI
	1985+(6)	0.2 - 0.3(7)	0.25	0.0	(6)
Exhaust BaP	All	Uncontrolled	1.0 - 6.0	0.0	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20	0.0	AP-42

(1) G/mi unless otherwise indicated.

(2) Deterioration rate taken to be 0 for diesels.

(3) Certification data on 1978 GM pickup truck (Ref. 2-14).

(4) HC + NO_x = 16 g/bhp-hr.

(5) Predicted standard per MSEF.

(6) Assumed.

(7) Proposed particulate standards for light duty diesels: 0.6 g/mi beginning in 1981, 0.2 - 0.3 beginning in 1983 - 1985 (Ref. 2-13).

Table 2-14. Vehicle Emission Factors -- Gasoline HDV

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study		
			Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1970	Uncontrolled	23.90	0.58Y	MSEF[3]
	1970-1973	275 ppm	18.54	0.53Y	MSEF
	1974-1978	(4)	22.02	0.53Y	MSEF
	1979-1982	(5)	5.22	0.53Y	MSEF
	1983+	2.85[6]	1.46	1.06Y	MSEF
Evaporative and Crankcase HC	Pre-1968	(7, 8)	7.70	0.00Y	MSEF
	1968-1980	(7, 8)	2.00	0.00Y	MSEF
	1981+	(7, 8)	0.30	0.00Y	MSEF
Exhaust CO	Pre-1970	Uncontrolled	272.90	3.06Y	MSEF
	1970-1973	1.5%	212.70	6.15Y	MSEF
	1974-1978	40 g/bhp-hr	218.80	6.15Y	MSEF
	1979-1982	25 g/bhp-hr	191.90	6.15Y	MSEF
	1983+	29.7[6]	15.38	10.54Y	MSEF
Exhaust NO_x	Pre-1970	Uncontrolled	8.80	0.00Y	MSEF
	1970-1973	Uncontrolled	12.80	0.00Y	MSEF
	1974-1978	(4)	10.50	0.00Y	MSEF
	1979-1984	(5)	9.10	0.00Y	MSEF
	1985+	5.35[6]	3.99	0.34Y	MSEF
Exhaust Particulates	Catalyst	Uncontrolled	0.02	0.00Y	PEDCo/EPA
	Catalyst, EA[9]	Uncontrolled	0.05	0.00Y	PEDCo/EPA
	Non-Cat., LF[10]	Uncontrolled	0.90	0.00Y	PEDCo/EPA
	Non-Cat., UF[11]	Uncontrolled	0.007	0.00Y	PEDCo/EPA
Exhaust BaP	Catalyst	Uncontrolled	0.30 μg/mi	0.00Y	PEDCo/EPA
	Catalyst, EA[9]	Uncontrolled	0.30 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., LF[10]	Uncontrolled	3.0 μg/mi	0.00Y	PEDCo/EPA
	Non-Cat., UF[11]	Uncontrolled	3.0 μg/mi	0.00Y	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20T[13]	0.00Y	AP-42

(1) 49 states; g/mi unless otherwise indicated.

(2) Y = cumulative mileage/10,000.

(3) Mobile Source Emission Factors (Ref. 2-1).

(4) HC + NO_x = 16 g/bhp-hr.

(5) HC = 1.5 and NO_x = 10 g/bhp-hr; or HC + NO_x = 5 g/bhp-hr, or HC = 1.0 and HC + NO_x = 9.5.

(6) Predicted Standard, MSEF.

(7) No evaporative emission standard.

(8) No crankcase emission standard prior to 1970; zero thereafter.

(9) Excess air.

(10) Leaded fuel.

(11) Unleaded fuel.

(12) Value assumed for this study.

(13) T = No. of tires/4

Table 2-15. Vehicle Emission Factors - Diesel HDV

Pollutant	Year(s)	Applicable Standard[1]	Values Used in This Study: Emission Rate, g/mi	Deterioration Rate, g/mi[2]	Source
Exhaust HC	Pre-1974	None	4.30	0.0	MSEF[3]
	1974-1978	(4)	4.50	0.0	MSEF
	1979-1982	(5)	4.50	0.0	MSEF
	1983+	2.85 g/mi[6]	2.85	0.0	MSEF
Evaporative HC	All	Uncontrolled	0.0	0.0	
Exhaust CO	Pre-1974	None	35.10	0.0	MSEF
	1974-1978	40 g/bhp-hr	27.00	0.0	MSEF
	1979-1982	25 g/bhp-hr	27.00	0.0	MSEF
	1983+	29.7 g/mi[6]	27.00	0.0	MSEF
Exhaust NO_x	Pre-1974		21.40	0.0	MSEF
	1974-1978	(4)	20.10	0.0	MSEF
	1979-1984	(5)	19.90	0.0	MSEF
	1985+	5.35 g/mi[6]	5.35	0.0	MSEF
Exhaust Particulates	All	Uncontrolled	2.0	0.0	PEDCo/EPA
Tire Wear Particulates	All	Uncontrolled	0.20 T[7]	0.0	AP-42
Exhaust BaP	All	Uncontrolled	4.6-24.6 μg/mi	0.0	PEDCo/EPA

(1) Grams/miles unless otherwise indicated.

(2) Deterioration rate taken to be 0 for diesels.

(3) Mobile Source Emission Factors (Ref. 2-1).

(4) HC + NO_x = 16 g/bhp-hr.

(5) HC = 1.5 and HC + NO_x = 10 g/bhp-hr; or HC + NO_x = 5 g/bhp-hr.

(6) Predicted standard, MSEF.

(7) T = No. of tires/4.

BaP emission rates were also taken from Reference 2-12. A range of values is indicated for diesel-powered vehicles. Both the high and low extremes shown in the table were used in evaluating the mobile source BaP pollutant dump. Tire wear particulate emissions were taken from AP-42 (Ref. 2-11) for all classes of vehicles.

Reference 2-1 recommends the use of a zero deterioration rate for all HDVD emissions, but does not address deterioraion effects in diesel LDV's and LDT's. Fifty thousand-mile EPA certification data for 1976 through 1978 model year LDVD's (not equipped with exhaust emission devices) indicate little or no deterioration for many of the vehicles tested. If exhaust gas recirculation (EGR) is adopted as a means of NO_x control in future diesel vehicles, some increase in diesel NO_x emissions with mileage accumulation may be anticipated. However, the magnitude of this effect cannot be predicted at this time. Given the uncertainty as to what control techniques might actually be employed for this purpose, it was decided to use a zero deterioration rate for all diesel emissions in all vehicle classes. The implications of this assumption are discussed in Section 5 of this report.

All values shown in Tables 2-8 through 2-15 were reviewed by EPA (Ref. 2-16), with no recommendations for change.

2.2.3 Stationary Source Emissions Inventory

The stationary source emissions inventory defines the pollutant dump for HC, CO, NO_x and total suspended particulates in each of the metropolitan areas selected for study for four time periods of interest: 1975/1976 base year, 1985, 1990, and the year 2000. This inventory is shown in Table 2-16. Values are presented for point and area source emissions in each of the four pollutant categories. In the case of total suspended particulates, fugitive dust sources are presented as a separate category. BaP is not shown because reliable estimates of region-specific dumps for this specie could not be found.

The point source emissions include stack emissions from such separately identifiable sources as power plants, refineries, and

Table 2-16. Stationary Source Emission Inventory -- Tons/Year

	Hydrocarbons			Carbon Monoxide			Oxides of Nitrogen			Suspended Particulates			
	Point Sources	Area Sources	Total	Point Sources	Area Sources	Total	Point Sources	Area Sources	Total	Point Sources	Area Sources	Fugitive Dust	Total
Manhattan													
1975	408	1,544	1,952	5,138	3,650	8,788	17,115	21,566	38,681	2,931	8,137	8,316	19,384
1985	408	1,544	1,952	5,138	3,650	8,788	17,115	21,566	38,681	2,931	8,137	8,316	19,384
1990	408	1,544	1,952	5,138	3,650	8,788	17,115	21,566	38,681	2,931	8,137	8,316	19,384
2000	408	1,544	1,952	5,138	3,650	8,788	17,115	21,566	38,681	2,931	8,137	8,316	19,384
St. Louis													
1976	48,403	44,827	93,230	164,218	166,500	330,718	313,812	53,214	367,026	44,538	9,437	1,246,663	1,300,638
1985	52,662	48,772	101,434	178,669	181,152	359,821	341,827	57,897	399,724	48,457	10,267	1,201,050	1,259,774
1990	55,034	50,968	106,002	186,716	189,311	376,027	356,804	60,504	417,308	50,640	10,730	1,181,329	1,242,699
2000	60,359	54,510	114,869	204,780	202,464	407,244	391,323	64,671	455,994	55,539	11,475	1,147,111	1,214,125
Phoenix													
1975	4,922	34,221	39,143	282	13,841	14,123	7,820	8,254	16,074	7,957	657	649,225	657,839
1985	4,911	28,958	33,869	260	15,587	15,847	7,061	9,127	16,188	11,242	949	636,085	648,276
1990	4,906	31,510	36,416	250	17,393	17,643	6,681	9,942	16,623	12,520	1,095	627,837	641,452
2000	4,901	40,202	45,103	239	21,733	21,972	6,301	12,521	18,822	15,914	1,351	634,421	651,686

manufacturing/industrial processes. Area source emissions include those resulting from the combustion of fuels (i.e., natural gas, LPG, distillate and residual oil and coal), in residential, commercial, and industrial sites. Other area sources include solid waste disposal facilities, railroads, and airports.

Fugitive dust sources include manmade sources such as dust from motor vehicles travelling on unpaved roads, agricultural tilling, construction activities and reentrained dust from paved roads. Windblown sources include dust from unpaved roads, agricultural fields, and undisturbed and disturbed soils. The fugitive dust values presented in the table include only particle sizes less than 30 μm in diameter. This is considered to be the maximum particle size that may remain indefinitely suspended (Ref. 2-11).

The methodology and data base associated with the emissions inventory for each of the study areas are as follows.

2.2.3.1 Manhattan

The emissions inventory for Manhattan was developed in part from information received in private communications with the New York State Department of Environmental Conservation (Ref. 2-17) and the New York City Department of Air Resources (Ref. 2-8) and from documents supplied by these agencies. The complete data base for the inventory is provided in References 2-17 through 2-20.

Power plant, incineration, and solvent evaporation emissions were supplied directly in tons per year (Ref. 2-17). Emissions from the combustion of fuel were developed from data on fuel consumption rates and New York State emission factors for each type of fuel.

Inquiries made to both the City and State of New York revealed that no information was available regarding suspended particulate emissions due to reentrained dust from paved streets (this is believed not to be a significant source of total suspended particulates in Manhattan). Numerous studies (Refs. 2-22 through 2-24) indicate that the emission factor for reentrained dust from paved streets is highly dependent upon several factors including land use (residential, commercial, industrial), the frequency and type of street cleaning operations, and meteorological conditions. In the absence of any specific data for Manhattan, an emission factor of 3 g/mi was assumed. This is approximately 10 percent less than the 3.3 g/mi reported for Kansas City (Ref. 2-12) and reflects in part an effect due to differences in land use and rainfall.

The base year for the Manhattan emissions inventory is 1975. The New York city and state agencies contacted both stated that all projections for Manhattan assume no change from the base year emissions inventory, based on the expectations that growth will be negligible and offset by a slight decrease in source emission rates. The Manhattan emissions, therefore, are held constant at the 1975 level to the year 2000.

2.2.3.2 St. Louis

The revised and updated state implementation plan for St. Louis is currently in preparation and is not yet available, according to discussions held with the Region VII office of EPA. It was recommended that the results of a Regional Air Pollution Study (RAPS) conducted by the EPA be used as the base year emissions inventory (Ref. 2-25). This extensive data base, covering the pollutants of interest, was obtained from the EPA Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina (Ref. 2-26). These data are shown in Table 2-16 for the year 1976. The RAPS study did not, however, include any projections beyond the base year. In the absence of specific projections of the emissions inventory, the values shown in Table 2-16 were based on projected population and employment growth rates for St. Louis (Ref. 2-27). These growths were found to be on the order of 0.9 to 0.95 percent per year. The magnitude of these projections was reviewed with the EPA Region VII office and was found to be consistent with a few preliminary projections being made as a part of the revised state implementation plan (Ref. 2-28). An additional adjustment was made to the fugitive dust emissions whereby it was estimated that the number of miles of unpaved streets would be reduced at the rate of 10 percent per 5 years (similar to Phoenix). This, in combination with an increase in VMT, resulted in an overall estimated reduction of 25 percent in the fugitive dust emissions from vehicular travel on unpaved roads by the year 2000.

2.2.3.3 Phoenix

The stationary source emissions inventory for Phoenix for HC, CO, and NO_x is based on a study conducted by the Arizona Department of Transportation for the Arizona State Department of Health Services as technical support for the preparation of an Air Quality Maintenance Plan for carbon monoxide and photochemical oxidants (Ref. 2-7). This report presents base year emissions for 1975. Projected growth and emission factors to the year 2000 are also presented, which when applied to the base year emissions inventory, permit the emissions to be determined for the time points of interest.

Total suspended particulate emissions for this region were investigated by TRW, Inc. for the years 1975 to 1985 (Ref. 2-29). The results of this study indicate that fugitive dust constitutes approximately 98 percent of the total suspended particulates inventory. Projections beyond the time frame covered in the TRW study were developed from guidelines provided by TRW (Ref. 2-30). Particulate emissions from power plants were held essentially constant beyond 1985. This projection considers that older, less efficient plants will be phased out, and that the remaining plants will be utilized to provide a near constant base power level, with additional power demand being supplied by nuclear plants outside the Phoenix area. Particulate emissions from area sources were projected to the year 2000 in proportion to population projections, while particulates from industrial/manufacturing plants were based on employment projections (Ref. 2-7). Fugitive dust emissions were held essentially constant beyond the year 1985 except for those sources resulting from vehicular travel on paved and unpaved streets. For these cases, projections to the year 2000 were developed as a function of projected VMT (Ref. 2-7) and a linear extrapolation of the ratio of unpaved to paved streets (Ref. 2-29). Fugitive dust inventories from each source were adjusted to include only particle sizes less than 30 μm, based on particle size distributions given in Reference 2-29.

The table entries for fugitive dust levels show a generally delcining characteristic to the year 1990, followed by an increase in the year 2000. This reversal in trend is due to the combined effects of a reduction in roads without curbs and a substantial increase in the number of off-road vehicles projected for the year 2000.

2.3 COMPUTATIONS

A sample calculation of the mobile source pollutant dump is given in Table 2-17, illustrating the method for the case of LDVD particulate emissions in Manhattan for the year 1990 at the 25-percent dieselization rate. Here the notation d or g is used in place of e to identify diesel or gasoline quantities, respectively. The quantity ΣMind shown in the table is not called for in the dump computation procedure, but was developed, along with ΣMing, for use in computing engine-specific composite emission factors required for the analysis of pollutant concentrations in the enclosed parking garage. For other local site analyses, involving mixes of whole vehicle classes, the composite emission factor was obtained from computed dump quantities and VMT data using the relation ΣDump/ΣVMT.

Table 2-17. Sample Mobile Source Dump Calculation -- 1990, 25-Percent Dieselization Rate, LDVD Particulates

1	2	3	4	5	6	7	8	9	10
Model Year	Age	Fraction In-Use $\left(\frac{Rine}{\Sigma Rine}\right)$	Annual Mileage $\left(MPY_{in}\right)$	3 x 4	$\frac{3 \times 4}{\Sigma 3 \times 4}$	Diesel Fraction (Find)	6 x 7 (Mind)	Mean Emission Rate (Cinpd)	8 x 9 (Einpd)
1990	1	0.1310	15,900	2082.9	0.1706	0.25	0.0426	0.25	0.0107
1989	2	0.1648	15,000	2472.0	0.2025	0.25	0.0506	0.25	0.0127
1988	3	0.1225	14,000	1715.0	0.1405	0.25	0.0351	0.25	0.0088
1987	4	0.0963	13,100	1261.5	0.1033	0.25	0.0258	0.25	0.0065
1986	5	0.0870	12,200	1061.4	0.0869	0.25	0.0217	0.25	0.0054
1985	6	0.0883	11,300	997.8	0.0817	0.25	0.0204	0.25	0.0051
1984	7	0.0801	10,300	825.0	0.0676	0.20	0.0135	0.60	0.0081
1983	8	0.0611	9,400	574.3	0.0470	0.15	0.0070	0.60	0.0042
1982	9	0.0522	8,500	443.7	0.0364	0.10	0.0036	0.60	0.0022
1981	10	0.0468	7,600	355.7	0.0291	0.05	0.0015	0.60	0.0009
1980	11	0.0274	6,700	183.6	0.0150	0.04	0.0006	0.60	0.0004
1979	12	0.0180	6,600	118.8	0.0097	0.02	0.0002	0.60	0.0001
1978	13	0.0059	6,200	36.6	0.0030	0.01	0	0.60	0
1977	14	0.0046	5,900	27.1	0.0022	0.0038	0	0.60	0
1976	15	0.0029	5,500	16.0	0.0013	0.0022	0	0.60	0
1975	16	0.0020	5,100	10.2	0.0008	0.0027	0	0.60	0
1974	17	0.0016	5,000	8.0	0.0007	0.0016	0	0.60	0
1973	18	0.0016	4,700	7.5	0.0006	0.0005	0	0.60	0
1972	19	0.0016	4,400	7.0	0.0006	0.0006	0	0.60	0
1971	20	0.0013	4,400	5.7	0.0005	0.0006	0	0.60	0
				Σ = 12,210			ΣMind = 0.2226		ΣEinpd = 0.0649

Notes: Enpd = ΣEinpd = 0.0649 g/mi (travel fraction-weighted)

$$\text{Dump} = \frac{0.0649 \times 6.11 \times 10^6 \text{ VMT/day} \times 365}{453.59 \times 2000} = 159.52 \text{ tons/year}$$

$$\text{Composite Emission Factor (LDVD)} = \frac{\text{Enpd}}{\Sigma \text{Mind}} = \frac{0.0649}{0.2226} = 0.29 \text{ g/mi}$$

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3. LOCAL SITE ANALYSIS

3.1 GENFRAL APPROACH

The local site analysis portion of this study examines the impact of LDV dieselization with respect to several urban road traffic facilities which are anticipated to be critical from the standpoint of diesel exhaust particulate concentration and odor effects. The analysis is executed on a microscale level, considering three general types of high density traffic facilities: the urban freeway, the urban street canyon, and the enclosed parking garage. Effects through the year 2000 are investigated at the same conditions selected for the general urban area analysis: three rates of LDV dieselization--base case, 10 percent, and 25 percent; and four time points in the period of interest--1975, 1985, 1990, and 2000.

The local site analysis is concerned with pollutant concentration effects rather than mass pollutant dumps. Unlike the areawide work, it is not region-specific in approach, but the calculation of concentration effects utilizes Manhattan statistics wherever traffic parameters are required to be evaluated.

In the following section, the general philosophies underlying the selected methods of analysis are broadly discussed to provide a vantage point for viewing specific calculation techniques later developed under each site case.

3.1.1 Particulates

3.1.1.1 Freeway and Street Canyon

Three basic approaches to the determination of particulate concentrations resulting from road traffic emissions were investigated for possible use in the freeway and street canyon analysis: (1) mathematical models of roadway pollutant dispersion effects, (2) correlations based on TSP sampling data, and (3) empirical relationships based on measured roadside air quality data. This study selected the third approach based on considerations discussed in the following paragraphs.

There is an extensive literature pertaining to mathematical models for predicting the dispersion of gaseous, nonreactive roadway-generated pollutants. If it is assumed that motor vehicle exhaust particulates disperse as a gas and are nonreactive over the time period from tailpipe emission to arrival at a measurement receptor, these models should be applicable to the case of particulate dispersions. This literature was reviewed; Appendix B provides a listing of the models evaluated. The review yielded two main conclusions.

(1) In no case has the accuracy of a model been verified for general use, nor is there a consensus as to which model or models tend to give results which most closely match "correct" values. It may be noted that the various models sometimes produce widely disparate results for a given set of input conditions (e.g., Refs. 3-1, 3-2, 3-3).

(2) All of the modeling techniques depend on either substantial meteorological input data which are generally unavailable for a specific site of interest, or they rely on one or more empirical constants which are test-measurement dependent, or they involve site-specific calibration factors which are hazardous to adjust or estimate for a specific traffic situation.

Though the literature on dispersion modeling is replete with claims of accuracy, independent confirmation of these claims is lacking and the issue of model applicability limits remains open.

The second approach examined involves the use of TSP measurements near roadways. Every large city has a TSP measurements program that provides technical support to state implementation plans required to demonstrate compliance with the TSP ambient air quality standards. Primarily, these programs are designed to measure the effects of large industrial sources, not motor vehicle exhaust emissions. Even in cases where the TSP sampling station is located near a major roadway, no record of traffic count in conjunction with the TSP measurements was made. More importantly, it is generally not possible to distinguish the motor vehicle contribution in the measured TSP sample.

One measurements program specifically oriented to roadway effects is reported in the literature (Ref. 3-4). This program was carried out in Seattle, San Francisco, and Philadelphia under the auspices of local control agencies and was primarily directed toward the measurement of reentrained dust from paved roads. Values were reported for motor vehicle exhaust particulate concentrations, estimated by measurements of suspended lead emissions and an assumed ratio of nonleaded to leaded fuel exhaust particulates. These data, however, are given in terms of general area concentrations; the contribution of specific roadways was not addressed.

The third, or empirical, approach, which was the one adopted by this study, utilizes measured roadside concentration data expressed in terms of a pollutant concentration index ψ, defined as

$$\psi_{xz} = \frac{\left(C_{xz} - C_b\right)}{Q}$$

where C_{xz} is the concentration of the species measured (e.g., CO, tracer gas, or particulate), at x distance horizontally from the roadway edge and z distance vertically above the ground, C_b is the background concentration of that species, and Q is the vehicle source emission flux from the roadway. Q is the product of the traffic-average emission factor (g/veh-mi) and the roadway traffic count (veh/hr). The assumption is made a priori that

$$(\psi)_{xz}\text{particulates} = (\psi)_{xz}\text{measured specie}$$

that is, the pollutant concentration index for particulate emissions will be equal to the pollutant concentration index for the test-measured specie. The measured data in each site category, expressed in the form of this index, are plotted as a function of x,z, and a characteristic ψ_{xz} correlation is established. Particulate concentrations for any projected traffic scenario are then obtained by multiplying the characteristic ψ_{xz} values by the roadway emission flux for particulates at projected traffic conditions.

The validity of this approach depends on several assumptions and conditions. One of these is the assumption that exhaust particulates will disperse in the same manner as the measured gas specie (usually CO or a tracer gas). This assumption is commonly accepted as valid, since vehicle exhaust particulates are quite small (generally in the size range from 0.1 to 10 μm)* and therefore tend to retain their position relative to the movement of the surrounding atmosphere for long periods of time. Confirmation of this was provided in a field test study conducted by General Motors (Ref. 3-5), which established that sulfate particulates from motor vehicle test traffic dispersed in the same manner as the test tracer gas (see Section 3.2.2). Measurements taken in the Los Angeles Catalyst Study (Ref. 3-6) indicate that the mass distribution of vehicle exhaust sulfate particulates falls about equally in the size range from 0.1 to 1.0 μm (same as diesel) and in the size range from 1.0 to 10 μm.

Another condition fundamental to the validity of the analysis is that the ψ_{xz} data must hold for a range of micrometeorological and vehicle source emission flux conditions. This aspect of the data was examined in detail (see Sections 3.2.2 and 3.3.2) and the condition was found to be satisfied.

A third condition is that the data encompass a wide range of roadway types, surrounding terrain features, traffic, and micrometeorological conditions, so as to ensure the general applicability of the correlation results. In the case of the urban freeway, the data base was found to be sufficiently broad to satisfy this requirement. The street canyon data were less suitable in this regard, and additional tools were required to buttress the analysis.

A final assumption that is tacitly made in using the data-based ψ_{xz} characteristic for projecting effects to future traffic conditions is that physical differences between the test and projected road vehicles

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*Diesel particulates are largely soot, fall in the size range below 1.0 m and have a low bulk density on the order of 0.075 g/cm^3.

(e.g., gross size, aerodynamic characteristics, exhaust heat release rate, class mix) will not grossly alter the ψ_{xz} relationship. In the present study, the data bases utilized in establishing the ψ correlation included vehicle traffic mixes varying from 0 to 22 percent HDV, yet no influences on the ψ relationship were perceived.

As mentioned above, the street canyon data are both less complete and less tractable to analysis than the freeway data. The principal problem stems from the fact that the field measurements are based on CO emissions which, for typical street canyon conditions, are very sensitive to traffic speed and vehicle operating mode, particularly for noncatalyst vehicles, which was the type in use at the time the measurements were performed. Thus, the traffic emission flux, Q, is a much more uncertain quantity than for the higher speed freeway tests. Details of the treatment of the data for this site case are given in Section 3.3.

3.1.1.2 Parking Garage

An experimental data base suitable for the analysis of the enclosed parking garage could not be found. This site case was treated on a purely analytical basis, considering a closed, ventilated chamber in which pollutant emissions and ventilation air are assumed to be completely mixed in the chamber atmosphere. The methodology used is described in Section 3.4.

3.1.2 Odor Effects

The basis for the quantitative assessment of diesel odor effects is the investigation by Turk (Ref. 3-7) in which odor is characterized in terms of D-numbers ranging (in increasing odor intensity) from 1 to 12. The D-numbers are defined by a logarithmic scale of concentration for a reference odorant as

$$\text{conc} \propto 2^{D-12}$$

or

$$\log \text{conc} \propto 2(D-12)$$

Public response to odor effects associated with a given D-number was determined in Reference 3-8, which records the response of approximately 300 persons to odors characterized by D-numbers ranging from 2 to 6. The test participants were off-the-street volunteers who were asked to grade each odor level in terms of one of the five categories of "pleasant," "neutral," "unpleasant," "very unpleasant," or "unbearable."

Reference 3-9 presents the results of an odor panel rating of the exhaust from two LDV diesels, an Oldsmobile and a Volkswagen Rabbit, operating in various modes (combinations of engine load and speed). The diesel exhaust was diluted 100:1, and the D-number of the exhaust for each vehicle in each mode was determined by a panel of trained odor judges.*

The odor methodology used in this study is based on the results of the above three references. The term Damb was established to represent the (unknown) D-number corresponding to the concentration of diesel exhaust at a given receptor location at a given site (urban freeway, street canyon, or enclosed parking garage), and the term DRamb was established to represent the dilution ratio of diesel exhaust at the same receptor position. Damb can be expressed in terms of Dmode (referenced to 100:1 DR), using the definition of Reference 3-7, as

$$\frac{(\mathrm{conc})_{\mathrm{amb}}}{(\mathrm{conc})_{\mathrm{mode}}} = \frac{2^{(\mathrm{Damb}-12)}}{2^{(\mathrm{Dmode}-12)}} = 2^{(\mathrm{Damb}-\mathrm{Dmode})}$$

Since (conc) $\propto$ 1/DR, this may be written with reference to the 100:1 Dmode data base as

$$\frac{100}{(\mathrm{DR})_{\mathrm{amb}}} = 2^{(\mathrm{Damb}-\mathrm{Dmode})}$$

*A trained odor judge was defined as one who had demonstrated the ability to assign correct D-numbers of the reference odorant, when the latter is diluted in accordance with the logarithmic scale defined in Reference 3-7.

or

$$\text{Damb} = \text{Dmode} + \frac{2-\log \text{DRamb}}{\log 2}$$

It is noted that Reference 3-9 also presents Dmode values for a dilution ratio of 550:1. An alternate procedure to the use of the above equation, then, would be to develop a semilog plot using the two Dmode values and to interpolate between the two points at the appropriate DRamb. The two methods give similar results for the operating modes of interest to this study.

At field test conditions, the dilution ratio may be obtained from the test gas concentration measured at a receptor, and from a calculated average value of the test gas concentration in the test-traffic vehicle exhaust. For a given receptor

$$(\text{DR})_{\text{test}} = \frac{\text{concentration in test-traffic vehicle exhaust}}{\text{concentration at test receptor}}$$

Assuming the same vehicle class distribution, and the same local urban meteorology, it may be shown that the dilution ratio for diesel exhaust in a projected dieselized fleet may be expressed as

$$(\text{DR})_{\text{proj}} = \frac{(\text{DR})_{\text{test}}}{f} \times \frac{(\text{TC})_{\text{test}}}{(\text{TC})_{\text{proj}}} \times \frac{v'_{\text{test}}}{v'_{\text{proj}}}$$

where $(\text{DR})_{\text{proj}}$ is the projected ambient dilution ratio, f is the fraction of vehicles in the traffic flow that are diesel-powered (all vehicle classes), TC is the traffic count, vehicles per hour, and v' is a quantity representing vehicle exhaust volumetric flow per mile. The volumetric flow term in this relation is the ratio of average vehicle exhaust flow for the test case (assumed to be all gasoline vehicles) and average diesel vehicle exhaust flow for the projected case. The exact value of this ratio will vary with the projection case, but it is reasonable, in view of the general lack of precision in defining odor effects, to assign a value of unity to this ratio.* Approximately, then,

$$(DR)_{proj} = \frac{(DR)_{test}}{f} \times \frac{(TC)_{test}}{(TC)_{proj}}$$

3.1.3 Emission Factors

While the general approach used in the analysis of local site effects is not region-specific, concentrations were calculated using composite emission factors for Manhattan, thereby generating values which are considered to be representative of Manhattan area effects. The composite emission factors are developed from the areawide dump analysis as

$$EF = \frac{\sum_{e,c} (Dump)_{cnpe}}{\sum_{e,c} (VMT)_{cnpe}}$$

where EF is the fleet composite emission factor for pollutant p for class c vehicles with engine type e in calendar (projection) year n.

In the analysis methodology utilized for the urban freeway and street canyon cases, the vehicle mix is equated to conditions in the overall Manhattan fleet (all vehicle classes and engine types represented). Two composite emission factors are involved, one for diesel exhaust particulates only, and one for the total of diesel and gasoline exhaust particulates. In the diesel case, the dump term in the numerator of the above equation is summed over all diesel vehicle classes, while in the case for the total vehicle mix it is summed over all vehicle classes and engine types. In both

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*It can be argued that while diesel vehicles have a higher exhaust flow rate per unit fuel consumption than gasoline vehicles, they also have lower specific fuel consumption. These factors tend to cancel each other.

cases, the VMT term is the same, representing the VMT sum for all vehicle classes and engine types. The emission factors so developed are listed in Table 3-1.

A different analysis methodology is employed for the enclosed parking garage. This site case is restricted to passenger cars (no taxis, LDT's or HDV's), and it is required to develop emission factors that are specific for each engine type. For the diesel particulate emission factor, both numerator and denominator of the above equation are summed over diesel LDV quantities. For the gasoline particulate emission factor, numerator and denominator are summed over gasoline LDV quantities. These factors are shown in Table 3-2. Included in the table are the fractions of total LDV VMT accumulated by diesel and gasoline cars, another parameter involved in the analysis.

3.2 URBAN FREEWAY

3.2.1 Methodology

The objective of the urban freeway analysis is to characterize particulate and odor effects in and near heavily travelled urban roadways. The analysis seeks to establish the profile of exhaust pollutant concentration versus distance from the roadway edge in order to identify possible adverse effects on the quality of the atmosphere exposed to motorists, business operations adjacent to the roadway, and residential communities in the roadway vicinity.

A purely empirical approach was adopted for characterizing the roadway concentration profile, based on the rationale given in Section 3.1. This approach utilizes field test measurements of CO, sulfate, and test tracer gases as a means to predict concentration effects for particulate emissions. The measured data are generalized in the form of a pollutant concentration index

$$\psi = \frac{\text{concentration above ambient}}{\text{source emission flux}} = \frac{\mu g/m^3}{g/mi\text{-}hr}$$

Table 3-1. Composite Emission Factors for Urban Freeway and Street Canyon Analyses (Manhattan Traffic Statistics)

Dieselization Rate	Projection Year	Diesel Exhaust Particulates (g/mi)[a]	Total Exhaust Particulates (g/mi)[a]
BC	1975	0.0425	0.301
	1985	0.0680	0.133
	1990	0.0941	0.137
	2000	0.146	0.163
10%	1985	0.0859	0.151
	1990	0.115	0.157
	2000	0.167	0.183
25%	1985	0.118	0.181
	1990	0.151	0.190
	2000	0.201	0.215
25% PC + 100% Taxis	1985	0.192	0.256
	1990	0.192	0.231
	2000	0.234	0.248

[a]Based on total VMT, all vehicle classes.
PC = passenger cars

Table 3-2. Emission Factors for Parking Garage Analysis (Manhattan Traffic Statistics)

Dieselization Rate	Projection Year	Diesel LDV Exhaust Particulates (g/mi)[a]	Gasoline LDV Exhaust Particulates (g/mi)[b]	Fraction of LDV VMT	
				Diesel	Gasoline
BC	1975	0.600	0.223	0.0011	0.9959
	1985	0.535	0.0202	0.0092	0.9908
	1990	0.325	0.0115	0.0099	0.9901
	2000	0.251	0.0105	0.0099	0.9901
10%	1985	0.485	0.0211	0.0505	0.9495
	1990	0.293	0.0121	0.0892	0.9108
	2000	0.250	0.0106	0.0999	0.9001
25%	1985	0.480	0.0217	0.1242	0.8758
	1990	0.292	0.0103	0.2226	0.7774
	2000	0.249	0.0105	0.2493	0.7507

[a]Based on LDV diesel VMT

[b]Based on LDV gasoline VMT

with the assumption that

$$(\psi)\text{particulate} = (\psi)\text{measured specie}$$

Treatment of the experimental data proceeded along the following lines. The data were first reviewed for stratification effects related to meteorology and traffic emissions. Finding no such relationships, the data were treated as a group and the experimental results for each roadway site were compared at equivalent test conditions. Patterns and trends of concentration as a function of distance from the roadway edge and traffic emission rate were characterized in terms of the ψ relation. These results were then converted to particulate concentrations by multiplying the characteristic ψ values by the roadway emission flux for particulates.

The analysis of measured concentrations focused on receptor data taken at or near three locations in the roadway site geometry: the roadway median, and positions at distances from the roadway edge of 100 and 300 ft. The median position is taken to be indicative of the average exposure level for occupants of vehicles on the roadway. The 100-ft position is considered to represent conditions to which people operating roadway businesses (e.g., service station attendants) may be exposed for periods of several hours or more each work day. The 300-ft position is taken to represent the daily exposure of inhabitants in nearby residences.

Receptor data taken near the roadway edge (about 6 to 15 ft) were also analyzed. This position was not of primary interest to this study, as it does not represent a position for which any long-term human exposure situations can be identified. This receptor location was included in the analysis to facilitate comparison with previous studies that have emphasized exposure levels very near the edge of the roadway.

A description of the urban freeway data base and the methods employed in its analysis is provided in the following section.

3.2.2 Data Base and Analysis Techniques

Various experimental data bases were examined for suitability to the analysis of the urban freeway. To be acceptable, the data base had to provide substantive information concerning line source emission flux, traffic count, local wind conditions, and concentrations measured at one or more of the receptor positions of interest. An additional requirement was that the number of receptor measurements be sufficient to permit a meaningful assessment of the data distribution. The data bases so selected are shown in Table 3-3 (a complete listing of the data bases examined is provided in Appendix B). Several other field studies potentially useful to the analysis were identified, including one on the Long Island Expressway in New York (Ref. 3-10) and several at sites in Texas (Ref. 3-11), but the data for these programs had not been released at the time this study was performed.

The GM experiment (Ref. 3-5) was conducted at a test track at the GM proving ground in Milford, Michigan. The terrain in the vicinity of the track was essentially level and open, with a growth of trees on the predominantly upwind side of the roadway, at a distance of approximately 400 ft from the roadway at the measurement section.

The test traffic in this experiment was closely controlled. Three hundred fifty-two cars were utilized. The cars were grouped into 32 packs of 11 cars each, for a total traffic count of 5462 veh/hr past the measuring station. The packs were maintained in symmetrical, constant relative positions at all times, travelling at a speed of 50 mph. All cars were catalyst-equipped, model year 1975 or 1976 domestics (the products of all four domestic manufacturers were represented). Average vehicle sulfate emission rates were established by pretest. In addition, a tracer gas, sulfur hexafluoride (SF_6) was released at constant, measured rates from eight vehicles that were distributed uniformly among the other test cars.

Air sampling was performed at 20 receptor locations. There were six instrumented towers, each equipped with three air sampling probes at heights above the ground of approximately 2, 12, and 31 ft. Two towers were located on the predominantly upwind side of the track, at distances of

Table 3-3. Urban Freeway Data Base

Organization	Date of Measurements	Measurements per Receptor	Roadway Characteristics: Location	Type	Surrounding Terrain	Emissions from Vehicles not on Roadway	Species Measured	Reference
GM[a]	Sept-Oct 1975	66	GM Proving Ground, Milford, Mi.	at-grade	nearly level, lightly wooded rural	no	sulfate particulate; tracer gas (SF_6)	3-5
SRI[b]	Jan-Feb 1975	45	Highway 101, near Santa Clara, Ca.	at-grade	level, open	no	CO; tracer gases (SF_6 & Freon)	3-12 3-13
SRI	Aug-Sept 1975	47	I-280 in San Jose, Ca.	above-grade (elevated on columns, not a solid fill)	urban streets and low buildings (near CBD)	yes	CO; tracer gases (SF_6 & Freon)	3-13
ANL[c]	June-July 1973	49	I-55, in suburbs of Chicago, Ill.	at-grade	level, open	no	CO	3-14
ANL	Aug 1973	31	I-90, in suburbs of Chicago, Ill.	below-grade	level, residential	"not significant"	CO	3-14
VH TRC[d]	June 1973-July 1974	21	I-495, in Fairfax County, Va.	at-grade	level, rural	no	CO	3-15
VH TRC	Jan-Aug 1974	15	I-64, in Norfolk, Va.	at-grade	uncomplicated scattered 1-story residential	no	CO	3-15

[a] General Motors Corporation
[b] SRI International
[c] Argonne National Laboratory
[d] Virginia Highway & Transportation Research Council

approximately 100 ft and 7 ft from the edge of the roadway. One additional tower was located in the roadway median, while three other towers were located on the predominantly downwind side of the track, at distances of approximately 13, 50, and 100 ft from the edge of the roadway. Two additional air sampling stations were installed on the predominantly downwind side of the track, at heights of about 2 ft above the ground, at distances of approximately 165 ft and 330 ft from the roadway. Three-component wind speed measurements were taken at each air sampling location; temperature was sensed on two of the instrumented towers.

Receptor measurements required for the determination of sulfate and SF_6 concentration were made in 30-minute intervals. The sulfate was collected on a filter for mass determination; concentration was established from the known constant air sampling rate. SF_6 concentration was established by post-test analysis of accumulated air samples.

Seventeen days of testing were performed, most days consisting of four successive 30-minute test periods, resulting finally in a total of 66 30-minute test periods. Sulfate background measurements were made immediately preceding and following the daily test sequence. Wind speed and wind direction were also measured and were reported, along with Richardson number (a measure of atmospheric stability), as 30-minute averages of the test data (Ref. 3-5).

From the standpoint of the assumptions made in the present study, it is significant to note that GM made a comparative analysis of the SF_6 and sulfate dispersion characteristics and concluded that the sulfate particulates behaved in the same manner as the tracer gas.

The SRI experimental program shown as the second entry in Table 3-3 examined CO dispersion effects on U.S. Highway 101 in Santa Clara, California (Ref. 3-12). This is a heavily travelled (at grade) urban freeway that serves commuter travel along a developed area southeast of San Francisco. The terrain at the measurement site is uncomplicated, consisting mainly of level fields within a radius of about 800 yds.

In addition to the CO generated by the roadway traffic, tracer gases were released from test cars which were driven on the roadway past the measuring site at the prevailing traffic speed. The test cars travelling in one direction released sulfur hexafluoride, while those travelling in the opposite direction released a Freon gas.

Thirty-five air sampling receptors were arranged symmetrically on both sides of the roadway and in the roadway median. There were five instrumented towers, each equipped with four air sampling valves at heights of 3, 10, 20 and 45 ft above the ground. One tower was located in the roadway median; the other four were used in pairs on each side of the roadway, one each at distances from the roadway of 35 and 50 ft. These towers also contained wind and temperature sensors. Fifteen additional air sampling receptors (each 3 ft above the ground) were located at distances ranging up to 300 ft from the nearest edge of the roadway.

Air samples were collected continuously during 1-hour data collection periods by means of sequential multiple bag samplers located at each of the 35 receptor positions. Each 1-hour air sample was analyzed for the concentration of CO, SF_6, and freon. A total of 45 one-hour periods of data were taken. Reference 3-13 provides a detailed breakdown of the hourly average traffic conditions (speed and traffic count), emission rate (both CO and tracer), micrometeorology (wind speed, direction, and Richardson number), and background CO concentration.

This field study estimated the roadway CO emission rate using an approach developed by the EPA and the California Air Resources Board relating highway CO emission factor to average vehicle speed. The roadway CO emission rate was also computed from the measured emission rates of the tracer gases and the measured ambient concentrations of CO and the tracer gases. The two methods yielded equivalent results on the average, but with considerable variance in individual values.

As indicated in Table 3-3, SRI also conducted a measurement program on Interstate Highway 280 in San Jose, California. The test roadway geometry was relatively complicated, consisting of two adjacent but separate four-lane roadways elevated on columns above an urban site near the San Jose central business district (CBD). Roadway-generated emissions were determined in the same manner described above for the Highway 101 data base. Also, the same two tracer gases were used, one each in the different directions of traffic flow.

Thirty-four air sampling stations were arranged about the roadway. Three instrumented towers were employed, one between the two elevated roadways, and one near the outside edge of each elevated roadway. Each of these towers was equipped with six air-sampling stations at heights varying from 3 to about 60 ft above ground (the roadway elevation at this point is approximately 23 ft).* In addition, three air sampling receptors 3 ft above ground were placed on either side of the roadway at distances from 65 to 300 ft from the projected edge of the elevated section. All other aspects of this test program are identical to those described for the Highway 101 data base. Forty-seven hours of data were collected.

The urban freeway data base also includes two measurement programs conducted by Argonne National Laboratory (ANL) on two urban freeways in the Chicago area (Ref. 3-14). Both were six-lane divided roadways, and in both cases the pollutant species measured was CO. In these studies, the roadway CO emission rate was computed from measured traffic parameters (traffic count, average speed, and traffic mix), EPA-derived emission factors, and Cook County vehicle registration data. The data at both sites were largely measured under conditions of atmospheric stability ranging from slightly to moderately unstable, according to the Pasquill classification used by ANL.

One of the ANL measurement sites was an at-grade section of I-55 at Cicero Avenue. This was a level, open location near some industrial facilities (e.g., truck terminals), that were infrequently used at the time of the test. Eight CO receptor positions (each 6 ft above the ground) were distributed asymmetrically about both sides of the roadway, at distances ranging from

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*The present study took the median concentration for this roadway as the average of three stations located 5 ft above the elevated roadway surface.

approximately 65 to 260 ft from the nearest edge of the roadway. All data were reported as one-hour averages. A total of 49 hours of data were collected.

The second ANL test measurement site was a below-grade section of I-90 at Lombard Avenue in Oak Park. Both sides of the roadway are residential areas with many large trees. The expressway is depressed approximately 20 ft below the surrounding terrain. Six CO receptors, each at a height of 6 ft above the ground, were arranged asymmetrically about both sides of the roadway at distances ranging from about 50 to 320 ft from the vertical planes of the roadway edge. The receptors were all positioned on ground level above the depressed freeway surface. Thirty-one one-hour data periods were reported.

The final two elements in the data base are test programs conducted by the Virginia Highway and Transportation Research Council (VHTRC) on two grade-level six-lane divided highways in Virginia (Ref. 3-15). CO was measured at both sites, with probes located at roadway distances of 12, 60, 110, 160, 260 and 360 ft on each side of the roadway. All probes were 5 ft above ground level; no median measurements were made.

One measurement site was a section of I-495 near Telegraph Road in Fairfax County. This is a predominantly rural area, characterized by level, essentially open terrain with scattered single family dwellings. The second site was a section of I-64 near Norview Avenue in Norfolk. Twenty-one one-hour periods of data collection were reported for the I-495 test and 15 one-hour periods were reported for the I-64 test. Both data sets were taken under Pasquill atmospheric stability conditions that were typically slightly to moderately unstable.

This completes the description of the urban freeway data base. In the following paragraphs, the methods and procedures used in analyzing these data are discussed.

The receptor elevations of principal interest to the present study are those at the heights normally associated with motorist and pedestrian air intake. Thus, the data base were screened to isolate the receptor data closest to road or ground level. The median receptors analyzed were located at heights 2 to 3 ft above the road surface, corresponding roughly to the air intake level for most passenger vehicles. The off-roadway receptors analyzed ranged in height from 2 to 6 ft above ground level.

An initial review of the data for receptors in an off-highway position showed an expected division of concentration level into upwind and downwind (defined here to include parallel winds) categories, with the downwind cases showing significantly higher concentration levels.* A similar examination made for receptors in the median location did not show this effect, presumably because this location is always in a downwind position relative to one direction of traffic. As a first step, then, the downwind data for off-highway receptors were isolated for further analysis, along with all the data for receptors located in the median position.

For each of these data points the pollutant concentration index ψ was computed as

$$\psi = \frac{C_x - C_b}{Q}$$

where C_x is the concentration ($\mu g/m^3$) at distance x from the roadway edge for the species being measured (CO, sulfate particles, or tracer gas), C_b is the background concentration for that species, and Q is the roadway emission flux in g/mi-hr. Q is obtained from the product of (1) the traffic-average emission factor for the measured species (g/veh-mi) and (2) the roadway traffic count (veh/hr).

The ψ values for each receptor were tabulated with the corresponding measured values of wind speed, wind direction relative to the roadway (classified as either parallel; that is, within 0 to 30° of the roadway; or crosswind, which encompasses the remainder of the 180° downwind

*The term downwind as used in this report includes all winds emanating from the roadway within a 180° sector based on the roadway axis.

sector), atmospheric stability (classified as either stable or unstable), and the roadway line source emission flux, Q. The purpose of this tabulation was to determine if the ψ values appeared to be stratified with respect to any one or more of these four independent variables. The presence or absence of statistical stratification determines whether all the measured data at a given receptor position should be characterized as a group, or whether only certain subgroupings of the data should be used.

A few explanatory remarks concerning this effort are appropriate. An ideal statistical approach would be to perform an analysis of variance that simultaneously tests the significance of each of the above four independent variables and determines if interactions exist among these parameters. However, even the simplest four-level analysis of variance (using only two classifications of each parameter, i.e., low vs high wind speed, stable vs unstable, parallel vs crosswind, etc.) would require 16 cells, each of which must have a minimum number of data points (ψ values) in order to generate statistically meaningful results. This requirement could not be met by any of these data bases. The maximum number of data points at a given receptor position was 66 or less. Missing data (due to instrument malfunction, or due to editing by the performing organization) or other site-specific factors generally restricted the number of applicable data points at a given receptor position to the range of 20 to 40. This limitation precluded an analysis of variance.

Analysis of covariance, in which a mathematical relationship is assumed between the dependent variable and one of the independent variables, reduces the number of cells required. Even this technique could be applied to only one receptor position of interest. This was for the GM sulfate data at a receptor located approximately 100 ft from the roadway edge. This analysis showed no statistically significant effect upon ψ (at the 95-percent confidence level) for any of the independent variables of wind speed, wind direction, or stability class (the roadway emission flux Q was held constant in these tests). It may be noted that a mathematical model representation of the GM experiment (Ref. 3-16) includes stability class as an independent variable, but shows only slight numerical dependence on this parameter. Thus, the lack of statistical significance of stability class in the analysis of covariance at a single receptor position is not surprising.

With the more formal tests for data stratification being inapplicable, this study utilized the following procedure to assess the influence of meteorological factors. The data were visually examined; in all cases where a stratification trend appeared to be possible, a t-test of significance was performed. For example, if the data examination indicated that high or low ψ values appeared to be associated with parallel vs crosswind conditions, the t-test compared the population of all ψ values for that receptor in the parallel wind case (regardless of the wind speed or stability class) vs all ψ values for that receptor in the crosswind case. The hypothesis tested was that the two populations had the same mean at the 95-percent confidence level. In general, the t-tests showed no significance with respect to any of the micrometeorological properties of wind speed, wind duration, or stability class (there were a few exceptions, but no trends were indicated).

Correlation analyses were also performed, whenever stratification effects were suggested, and when numerical values could be assigned to the independent variable (e.g., wind speed). These analyses generally showed little identifiable correlation effects (correlation coefficients were typically ≤ 0.4).

One possible explanation for the lack of meteorological influence observed in this analysis is the inherent inaccuracy in trying to represent the complex, three-dimensional, time-varying air velocity field near a heavily travelled roadway using single, fixed values for wind speed, wind direction, and atmospheric stability class. Reported values of these parameters represent average results determined over the time interval of data collection (typically one hour), and were taken at only one location. The hourly average wind speed and direction measured at one location may bear little relationship to pollutant concentration effects measured at other locations in the roadway site.

In summary, this study found no basis for stratifying the ψ data at the receptors of interest.

Following this analysis, the data for each receptor position was examined in terms of conventional parametric statistics (e.g., mean, standard deviation). The actual frequency distribution of the data was also studied. In many cases, the distribution was found to deviate significantly from a normal characteristic. This was not unexpected in view of the relatively limited number of data points and the data scatter which usually accompany field measurements of complex physical processes. Of particular concern here was the treatment of extreme values in the data distribution, which tend to have a swamping effect in conventional parametric statistics (a blanket deletion of apparently extreme values was considered unsatisfactory). This problem is largely avoided by using nonparametric statistical techniques. Accordingly, and in consideration of the observed nonnormal nature of the data distribution, it was decided to use a nonparametric approach to the data analysis. In this approach, ψ values at the 50th-cumulative percentage level were determined from the complete data set for each receptor and were used to establish the profile of ψ versus distance from the roadway edge.* The 50th-percentile ψ level is considered to provide a reasonable estimate of conditions that are frequently encountered.

3.2.3 Characterization of the Pollutant Concentration Index ψ

Fiftieth-percentile ψ values for each roadway data base are plotted in Figure 3-1. Considering first the GM data, note that the independent measurements of tracer gas and of sulfate particulates gave essentially the same ψ values at all receptor positions. The results of the tracer and CO measurements for the SRI Highway 101 data base are in reasonably good (mutual) agreement for all receptor positions except the median; the tracer data yield the higher ψ value in all cases.

*The data were also examined at other percentile levels and were found to produce similar ψ profiles.

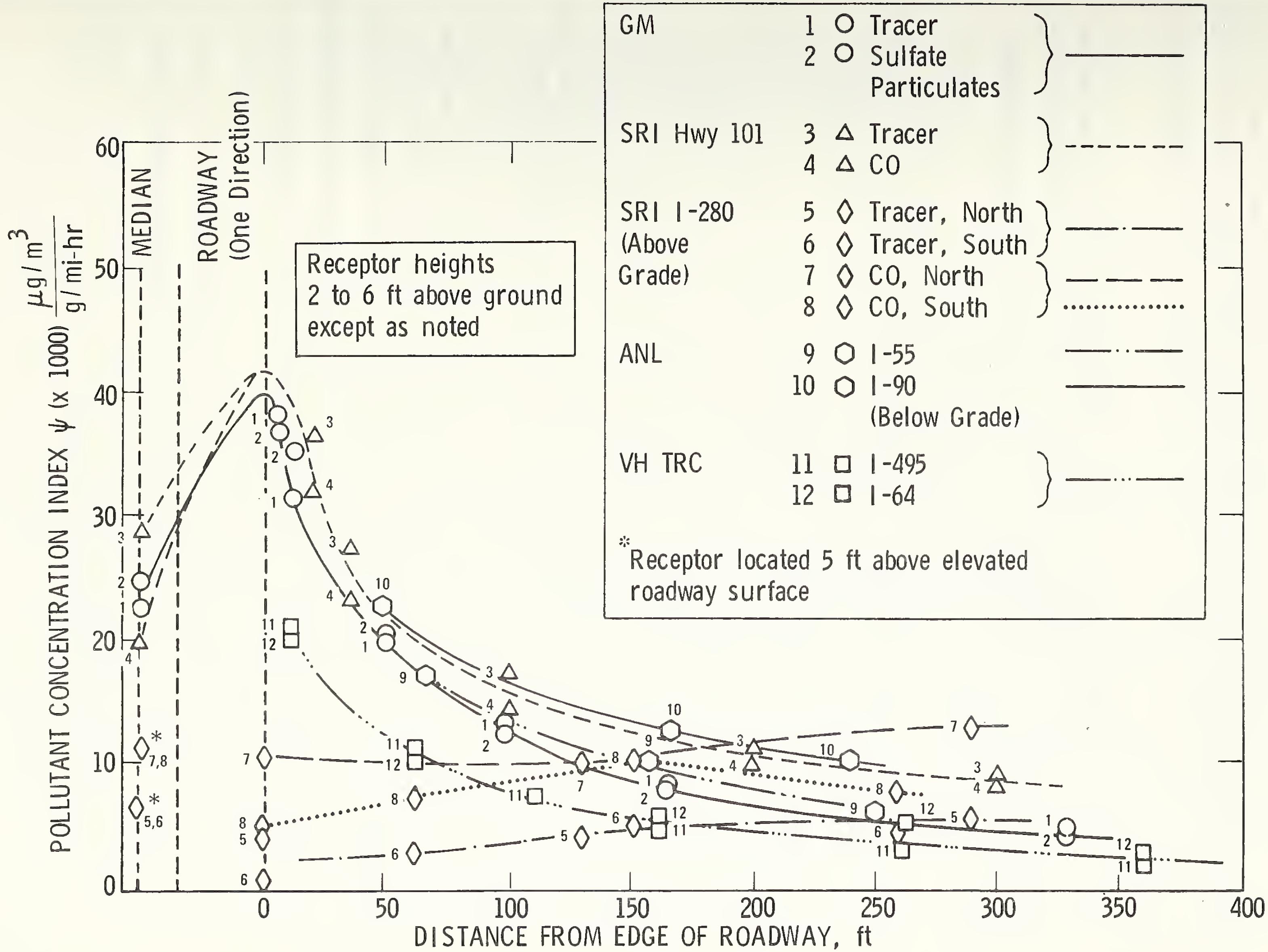

Figure 3-1. Fiftieth-Percentile ψ Values for Urban Freeway Data Base

The ANL data for I-55 (at-grade) lie close to the GM data, while the ANL data for I-90 (below grade) are extremely close to the values for SRI Highway 101, an unexpected result in view of the differences in grade geometry.

The data for the two Virginia sites (VHTRC) are in close mutual agreement, but lie below the other data bases. This might be explained by the fact that the local terrain conditions for these two sites provide the least obstruction to air movement of any of the data bases.

The SRI I-280 data reflect conditions near ground level for a roadway that is elevated on pillars. As expected, these data show a declining trend with decrease in receptor distance from the vertical to the roadway edge. At distances from the roadway of approximately 200 ft, the I-280 data blend with the dispersion patterns of the other data bases, except for the CO data taken north of the roadway. These data fall above all other plotted points at distances greater than about 250 ft. The reason for this behavior is not known precisely, but it may be related to emissions from vehicles on other roadways in the test vicinity (the test site was a few blocks south of the San Jose CBD.) The CO measurements at receptors south of the roadway may also be influenced by this factor; those data lie above tracer gas measurements taken at the same receptor positions. In this regard, it may be noted that the I-280 north and south tracer data are not distinguishable, one from the other, in terms of trend. It will also be noted that the median values for this roadway lie well below those for the median receptors on the at-grade roads. This is probably due to superior air circulation conditions associated with the elevated road geometry. The I-280 median data are considered not to be representative of typical freeway effects.

In summary, the trends and relative positions of the plotted data can be rationalized in some cases but cannot be explained readily in others. As with all experimental results, the scatter observed may be due in part to inaccuracies of measurement. In the present study, the error effects are undoubtedly compounded in the calculation of ψ by uncertainties in estimates of traffic count, average speed, and model year mix, and in the determination of vehicle emission rate for the measured specie. Only in the GM experiment were all of these parameters systematically measured and controlled.

Based on these considerations, it was concluded that the data base did not justify a differentiation of ψ characteristics with respect to freeway geometry and terrain features, except in the case of the elevated freeway where empirical evidence and intuitive reasoning both argue that concentration effects will not be critical at ground level for positions near the roadway edge. Accordingly, this study established a characteristic ψ profile by fitting a curve to the bulk of the at-grade and below-grade data. The selected profile lies in the midrange of the data spread at the median position, toward the high side of the data scatter at the 13-ft position, and generally in the midrange of the data spread at the more remote locations (roughly fitting the GM and I-55 experimental results). This characteristic was taken to represent freeway site effects nationwide, and was used as the basis for computing particulate concentration levels. Consideration was also given to possible worst-case effects, and for this purpose computations were performed for a ψ curve fitted to the upper extreme of the data scatter, defined roughly by the ANL I-90 and SRI Highway 101 study results.

The freeway-representative ψ characteristic is displayed in Figure 3-2. Also shown is the ψ curve fitted to the limits of the data spread, identified as "data base extreme." A 95th-percentile ψ characteristic, derived from the data bases most closely matching the representative 50th-percentile ψ curve, is included in this figure to provide an indication of the dispersion in receptor measurements data. The 95th-percentile ψ characteristic is also used in the analysis of freeway odor effects.

Particulate concentrations based on the 50th-percentile generalized characteristic were calculated from

$$\text{conc} = \psi_{50} \times \text{EF} \times \text{TC}$$

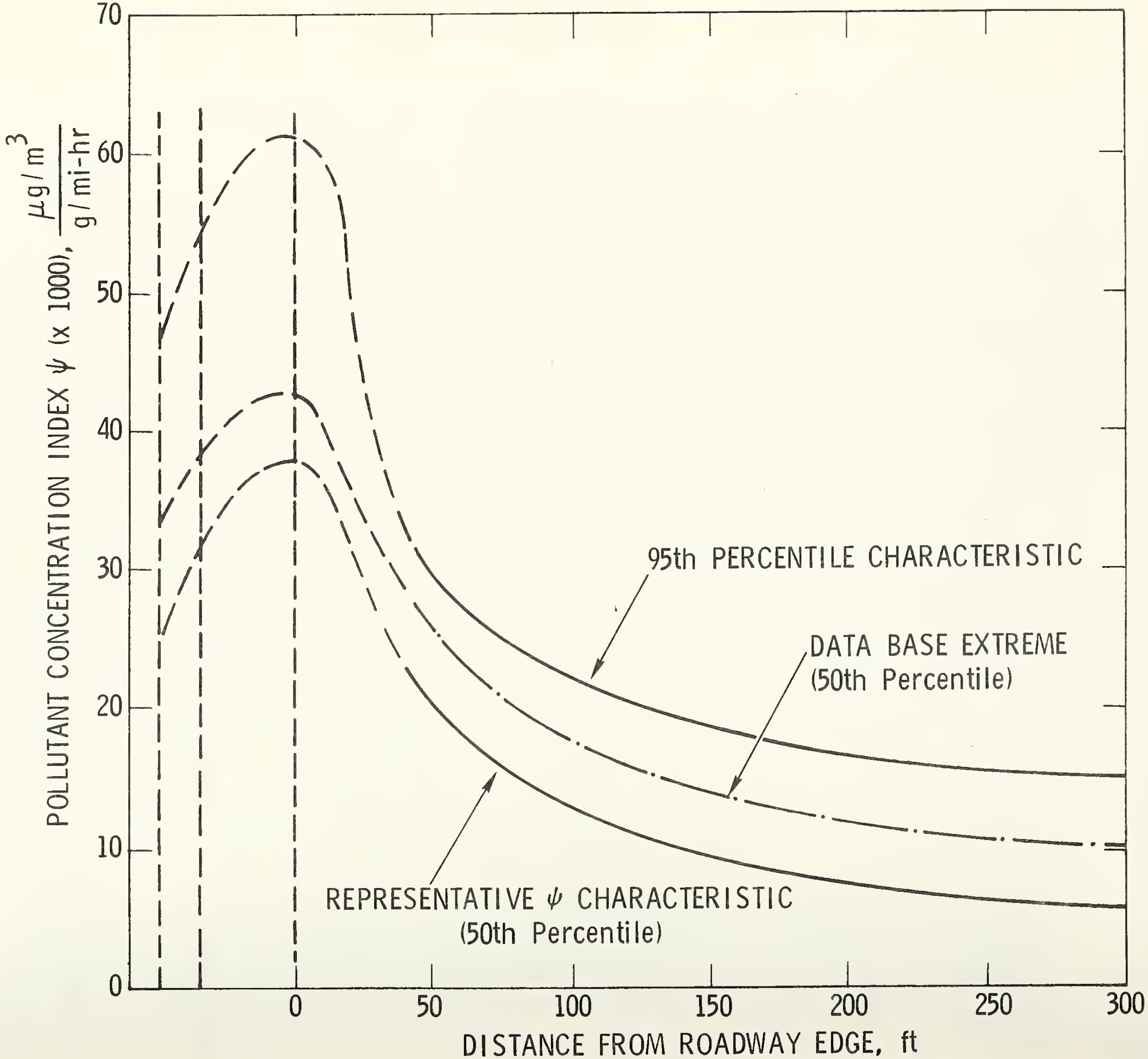

Figure 3-2. Characteristic ψ Profiles for Urban Freeway

where

conc = particulate concentration above ambient, $\mu g/m^3$

ψ_{50} = 50th-percentile value of ψ at the receptor location (from Figure 3-2)

EF = particulate emission factor applicable to the analysis case (Manhattan statistics)

TC = vehicle traffic count (both highway directions), veh/hr

3.3 STREET CANYON

3.3.1 Methodology

The objective of the street canyon analysis is to characterize particulate and odor effects in heavily travelled urban streets flanked by tall buildings. These structures interact with the surrounding air flow so as to inhibit the circulation and removal of pollutants in the channel formed by the buildings and street. The analysis seeks to define the profile of exhaust pollutant concentration vs height in order to identify possible adverse effects on both the ventilation air in the canyon buildings and the atmosphere at street level.

Whereas a substantial body of experimental data was available for use in analyzing pollutant concentration effects for the urban freeway, the available data base in the case of the street canyon was found to be limited. Two types of useful information were identified: (1) comprehensive but short duration CO measurements at multiple elevations in several street canyon sites and (2) long-term (continuous) CO measurements at single probe locations. The first group of data was accompanied by information on wind speed, wind duration, and vehicular traffic count, while the second group of data was not circumscribed by traffic count or meteorological information.

Mathematical models of street canyon transport phenomena were reviewed for possible use in augmenting the data base, but were rejected as a group on a variety of counts (e.g., complexity, meteorological unknowns). One of these, APRAC, bears a special relationship to the street canyon test measurements mentioned above and was therefore utilized as a supportive tool in characterizing the data trends.

The methodology employed in this analysis generally follows the method described for the urban freeway. That is, the experimental data were first reviewed for stratification effects related to meteorology and traffic count (where such information was provided). Finding no such effects, the data were treated as a group and the experimental results for each site were compared at equivalent test conditions. Patterns and trends of concentration as a function of height and traffic emission rate were characterized. The results were then directly scaled to particulate and diesel odor concentrations on the basis of the assumption that these emissions disperse in the local environment in the same manner as the species measured (CO).

A description of the data and the methods employed for this analysis is provided in the following paragraphs.

3.3.2 Data Base and Analysis Techniques

Four experimental programs specifically designed to establish exhaust pollutant concentration profiles in urban street canyons are reported in the literature. Two of these efforts were conducted by SRI International at sites in St. Louis, Missouri (Ref. 3-17) and San Jose, California (Ref. 3-18). Another test program was conducted by Vanderbilt University in Nashville, Tennessee (Ref. 3-19). A fourth program, conducted by New York City, examined six sites in the midtown Manhattan area (Ref. 3-20). All of these experiments involved the measurement of CO concentrations at multiple locations in the canyon geometry.

In the St. Louis study, CO measurements were performed in each of two intersecting street canyons (Broadway and Locust Streets) in the central business district. A matrix of 15 CO measurement receptors was installed in a vertical plane across each canyon. There were five CO receptors in a vertical line in front of each building face, located about 9 ft from the building, at heights above the street of 12, 20, 40, 75 ft, and at the top of the building. An identical array of five CO receptors was located near the opposite wall of the street canyon. The height of the building-top CO receptors varied from about 100 to 125 ft above the street. The buildings at the measurement section varied in height from 9 to 11 stories. A horizontal array of three equally spaced receptors was installed across each street canyon at heights of approximately 20 ft above the street. Two additional CO receptors were uniformly spaced across the top of the canyon in a line connecting the two rooftop CO receptors.

Wind and temperature measurements were taken at several of these receptor positions. Wind speed and direction, and CO measurements, taken at stations located on a tower atop a nearby building, were also obtained.

Vehicle traffic counts were measured in each street canyon. SRI used the following relationship to express the vehicle CO emission factor as a function of traffic speed

$$EF_{CO} = 700\ (\overline{V})^{-0.75}$$

where EF_{CO} is in g/veh-mi and $\overline{V}$ is the average traffic speed in the canyon in mph (this relationship predicts CO emission factors which agree closely with results obtained using EPA-recommended calculation procedures). On the basis of some local traffic speeds measured within the hours of 0730 to 1730, SRI assumed a constant average vehicle speed (and hence a constant emission factor) which was applied to all hours of the day for each street canyon. The assumed constant average speeds were 8.5 mph for Broadway and 5 mph for Locust.

Measurements were performed from late August through mid-October of 1971. The goal was to perform simultaneous data collection from all receptors for 24 hours a day. Because of instrumentation difficulties, the actual hours of simultaneous collection of CO and traffic count data varied from 0 to 24 hours, with about 13 to 18 hours being a representative figure for most days. The data, which were aggregated into 7-1/2 minute periods, were obtained for the present analysis in the form of a summary data tape (Ref. 3-21).

In the San Jose work, CO measurements were taken at seven locations near the intersecting streets of First and San Antonio in the central business district. Each measuring location consisted of a single vertical array of five CO receptors, spaced at equal intervals from 10 ft above the street to the top of the building. The receptors were positioned 10 feet from the building walls. Wind speed and temperature measurements were taken at some of these receptor positions. There were no horizontal cross-canyon CO measurements in the San Jose study. At the two measurement sections of primary interest to this study (at opposite sides of a midblock location on First Street), the building was three stories high on one side and five stories high on the other. These were the only midblock locations in the San Jose data base. Additional measurements at two intersections were made but were not utilized in this study because of the difficulty of assigning appropriate CO emission rates to the traffic conditions at these locations.

Measurements were taken in the period from mid-November through mid-December 1970. CO data was generally collected for about 5 or 6 hours a day, primarily during the morning, midday, and evening rush periods. These data are contained in a summary data tape (Ref. 3-20), aggregated in groups of five-minute data collection periods.

The Nashville measurements were made on Broadway Avenue, between 8th and 9th Avenues, in the Nashville central business district. The average building height along this block was stated to be approximately 75 ft, with no building less than three stories. The CO measurement system consisted of three horizontal arrays across Broadway. Each of these arrays consisted of five sets of three CO receptors in a vertical alignment at heights of 18, 21, and 24 feet above the street. One stack of three CO receptors was located at each building wall and the other three were spaced uniformly across Broadway. The three sets of horizontal arrays were spaced at intervals of 54 ft along Broadway, for a total of 45 CO receptor positions, 15 at each of the three heights of 18, 21, and 24 ft.

The vehicle traffic count along the test section of Broadway was measured. The test program was conducted over the time period from December 1969 to December 1970 during the autumn and winter months. Eleven periods of data collection are mentioned in the detailed description of that study

(Ref. 3-23), but data are given for only two 24-hour periods of data collection. These days are said to be representative of "typical meteorology" and "unfavorable meteorology" (i.e., tending to give high CO readings), respectively. The CO data for each receptor, and the average CO values at the 18- and 24-ft heights, were tabulated along with the vehicle traffic count for each 30-minute period of each 24-hour data collection period. Results at the 21-ft height were not given because they were reported to be statistically indistinguishable from the readings at the 18- and 24-ft heights.

The study description stated that traffic speed was measured in some cases but no data were given. Furthermore, CO background information was not provided. Because of these deficiencies, the Nashville data were only utilized in the present analysis as a checkpoint on characterization results derived from more complete data sets.

The principal output of the Manhattan experiment (Refs. 3-20, 3-24) was a correlation of street level CO minus rooftop CO as a function of a meteorology-dependent diffusivity factor and the canyon height to width ratio. The measured data from this program could not be obtained for use in the present study, but the correlation just described was employed as an additional analysis tool.

In summary, the principal useful elements in the data base comprising multiple receptor CO measurements were the St. Louis and San Jose projects. Other data in this class were utilized, to the extent possible, for comparative purposes. Also utilized in this sense was the APRAC street canyon dispersion model (Refs. 3-17, 3-18), which was developed by SRI using the St. Louis and San Jose data for calibration purposes. In that work, it should be noted, SRI aggregated the data into categories of rooftop wind speed and wind direction. APRAC CO predictions agree only moderately well with the data so aggregated.

Data tapes (Refs. 3-21, 3-22) from the SRI St. Louis and San Jose experiments were obtained and were subjected to a comprehensive search and computation procedure to produce selected hourly average results. For the

St. Louis data tape, hourly average CO concentrations were computed for each of the 15 receptors located in each of the intersecting canyon streets (Broadway and Locust), along with hourly average traffic count (vehicles per hour), rooftop wind speed, wind direction, and rooftop CO concentration. This produced approximately 500 hourly averages for each of 15 receptors in each street canyon.

A similar procedure was utilized for the San Jose data tape, but fewer data points could be analyzed due to limitations in the traffic count and background CO data provided in that source.

The individual data points so obtained were examined for meteorological and traffic emission stratification effects by a procedure similar to that described in Section 3.2.2 for the urban freeway analysis. No consistent data stratification effects were observed, so that all data reported for a given receptor height were analyzed as a group.

Alternative means for correlating the data were examined. The most useful approach appeared to be a plot of the pollutant concentration index ψ for various heights near the building walls which form the canyon. The parameter ψ is defined in a manner similar to the urban freeway case:

$$\psi_{xz} = \frac{\left(CO_{xz} - CO_b\right)}{Q_{CO}}$$

where CO_{xz} is the CO concentration in $\mu g/m^3$ measured at x distance horizontally from the canyon wall and z distance vertically above the street surface, CO_b is the CO background concentration in $\mu g/m^3$, and Q_{CO} is the CO emission flux due to canyon traffic (g/mi-hr). Q_{CO} is the product of the canyon traffic average emission factor (g/veh-mi) and the canyon traffic count (veh/hr).

These data were used in conjunction with directional trends computed from the APRAC model to develop generalized relationships of ψ vs H, where H is the receptor height (near the building wall). In these relationships, H ranges up to 120 ft (10 story building), the maximum canyon height encompassed by the data. Details of the development of these relationships are provided in Section 3.3.3.

In addition to the data described above, long-term (continuous) measurements of CO at single probe locations, such as used by city or county regulatory agencies for data input to Air Quality Implementation Plans, were utilized. These long-term measurements tend to average out random perturbations of traffic density, traffic mix, and meteorological effects, and in this sense are more directly applicable to the determination of mean conditions than the short-term experimental measurement programs.

CO monitoring data in several major city sites were evaluated, with a view toward defining conditions representative of worst-case street canyon conditions. The site selected for this purpose was a CO monitoring station in midtown Manhattan, located on 45th Street between Lexington and Park Avenues. This station is located on a relatively narrow street with tall buildings on either side. Data (Ref. 3-25) show that this location is within the one-square mile grid of Manhattan that has the highest ambient air readings for all three regulated mobile source pollutants (HC, CO, NO_x). Continuous CO monitoring at this site has been in progress since 1970. Measurements are made at a single probe located at a height of 5 ft above the curb.

While traffic volume at the 45th Street site is moderate compared to that on the avenues at right angles to 45th Street, the intersection at Lexington Avenue is considered to have a significant impact on air quality in the vicinity of the problem.

Long-term CO measurements at this station (Refs. 3-26, 3-27) show a relatively uniform data trend over the time period from 1970 through 1973. The 1973 data were selected for analysis. From this set of one-hour-average CO concentrations measured over the entire year, the 50th-percentile concentration level was established. This was considered to represent baseline year conditions for curb level CO concentration in a worst-case street canyon configuration. Projections of particulate concentrations for various dieselization scenarios were determined from this baseline using the calculation procedure outlined in Appendix C.

3.3.3 Characterization of the Pollutant Concentration Index ψ

As described for the case of the urban freeway, the street canyon analysis assumes that local dispersion effects for mobile source particulate emissions will be similar to those for CO and other pollutant species for which measured concentration data are available. On this basis, the measured data can be generalized in the form of a pollutant concentration index

$$\psi = \frac{\text{concentration above ambient}}{\text{source emission flux}} = \frac{\mu g/m^3}{g/mi\text{-}hr}$$

so that

$$(\psi)\ \text{particulate} = (\psi)\ \text{measured specie}$$

The SRI street canyon measurements provide sufficient information to estimate a ψ profile versus height. This was done, using the above relation, by the following process.

1. Background values of CO concentration were subtracted from the hourly average CO reading at each receptor (where receptor pairs were used, as in the case of the St. Louis field study, the higher of the two readings was taken to represent the concentration at that height). Background concentrations were those measured or estimated by SRI.

2. ψ values were established by dividing the concentration above ambient by the product of the traffic CO emission factor and the traffic count (veh/hr). CO emission factors were specified by SRI (Refs. 3-17, 3-18).

3. For each receptor, the ψ values were ordered and the magnitude of ψ at cumulative percentage levels of 50 percent and 95 percent were determined. The 50-percent level ψ is considered to represent a frequently encountered condition and was used in this study as the basis for projecting LDV dieselization effects. The 95-percent ψ level represents a near-maximum, infrequent condition and is developed only to indicate the variability of the data.

4. The 50th- and 95th-percentile data were each plotted versus receptor height and curves were fitted to the plotted values.

The smoothed 50th-percentile data are shown in Figure 3-3, along with a range of results obtained from the APRAC model as applied to all sites. (It should be noted that the APRAC results cannot be assigned an exact ψ percentile ranking; however, they are roughly comparable to the 50th-percentile case in the sense that a frequently observed site wind speed [2 m/sec] was used in the model calculations.) It can be seen that the data show considerable scatter, and it is useful at this point to consider some of the factors which could contribute to this effect.

In the first place, differences in street canyon configuration undoubtedly influence the results. At curb level the relative ψ magnitudes shown for Broadway and Locust Streets were found to agree well with the correlation for Manhattan relating street level CO to canyon H/W (Ref. 3-24). At higher elevations, the APRAC model suggests a small influence due to geometry. In general, no reliable means is available to evaluate the relative significance of this effect.

One undoubtedly important effect is the CO emission factor, which is highly influenced by vehicle speed, particularly in noncatalyst cars which comprised the fleet at the time the SRI field studies were conducted. The speed values used in these experiments were largely estimates based on measurements or indications of traffic flow near (but not at) the test measurement site; in the case of San Jose, speed was referenced to conditions in the general San Jose CBD. Constant average values for all test conditions were used, resulting in constant average emission factors through the relation given in Section 3.3.2. Aside from the assumption of constant average speed for all hours of data collection (in itself troublesome), the effects of queuing at signalized intersections can have a significant impact on the time-averaged traffic emission rate. It may be shown that an average speed of 7.5 mph consisting of a 20-mph run for 500 ft combined with a 30-second idle (at an intersection) would produce 50 percent more CO than a constant speed of 7.5 mph.

The problem of characterizing CO emissions for traffic influenced by a signalized intersection has been analyzed in the literature

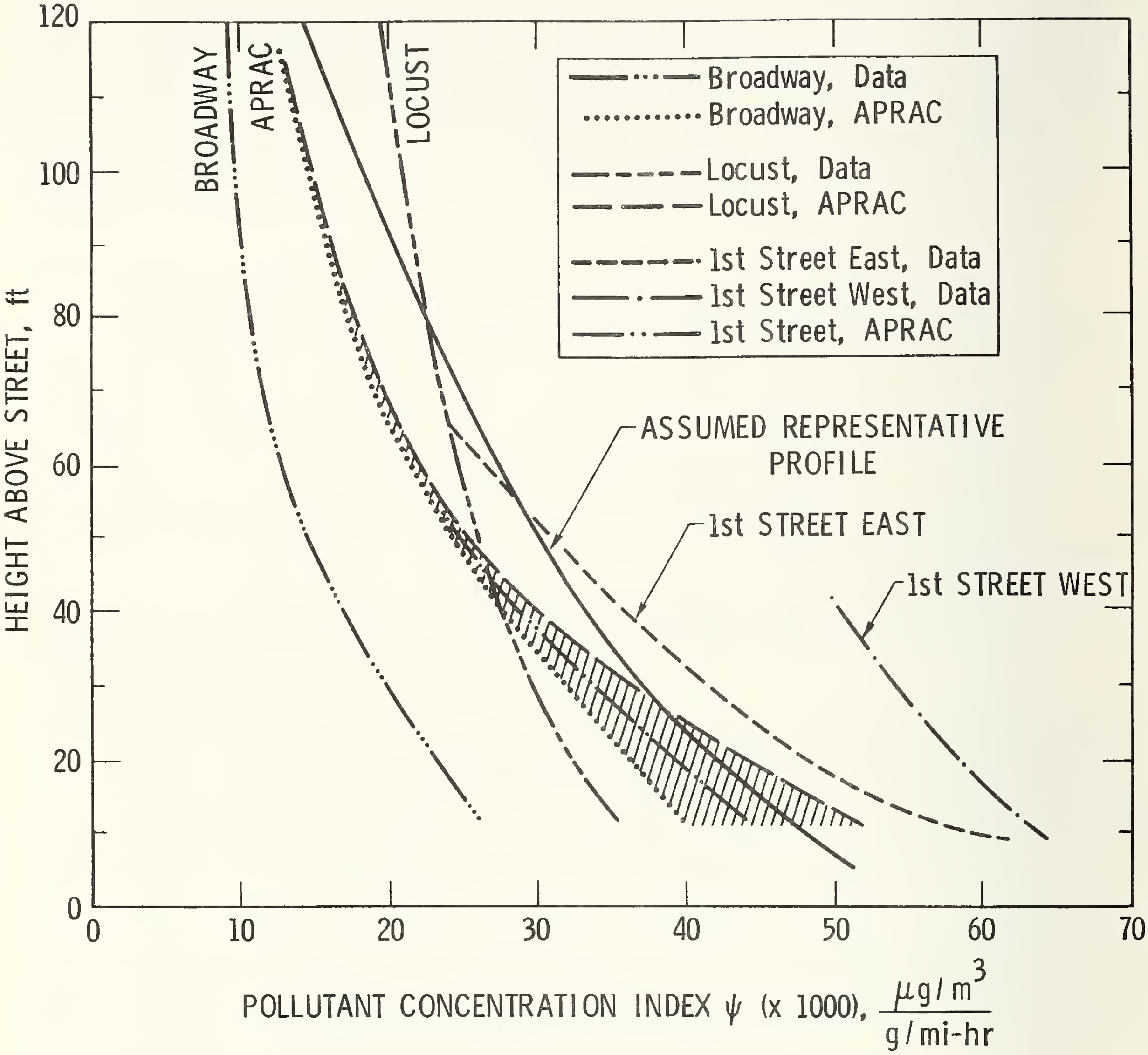

Figure 3-3. Characterization of the Fiftieth-Percentile ψ Profile for Street Canyons

(e.g., Ref. 3-28). Although the required methodology has been defined, it requires extensive measurement and observations of the traffic. This information is not contained in any of the street canyon data bases.

An additional source of uncertainty for computations performed using the San Jose data is the lack of traffic count information. This was provided only for portions of one day of data collection. The more detailed traffic information, which was obtained at the time of the measurements (1970) from the San Jose Traffic Department, are no longer available. Therefore, this analysis assumed that the reported one-day traffic characteristics defined conditions for all days of data collection.

Given these uncertainties, it is difficult to choose an appropriate profile to use as the 50th-percentile street canyon characteristic. The curve in Figure 3-3 labeled assumed representative profile represents an approximate average of the St. Louis data at the higher street canyon elevations. At the lower levels, the assumed representative profile was shaped to reflect the San Jose data and the APRAC prediction.

Both the 50th-percentile characteristic selected in Figure 3-3 and the results of a similar analysis for 95th-percentile values of ψ are shown in Figure 3-4. Included in this plot are data points derived from some of the other street canyon test programs discussed in Section 3.3.2, none of which were amenable to a height/concentration profile analysis.

The Nashville data were reported for heights of 18 and 24 ft for a day of "typical meteorology" and for a day of "unfavorable meteorology." Both sets are plotted in the figure. As might be hoped, the favorable meteorology set lies near the 50th-percentile representation. The unfavorable meteorlogy set, which might be expected to match the 95th-percentile representation, lies well below this curve.

Included in Figure 3-4 is a data point representing the Manhattan curbside CO receptor at East 45th Street. The calculated ψ values for this data set are somewhat weak because of the uncertainty in the traffic sources which might influence the probe reading. The plotted points are based on an "effective" traffic count represented by the sums of the traffic rate on

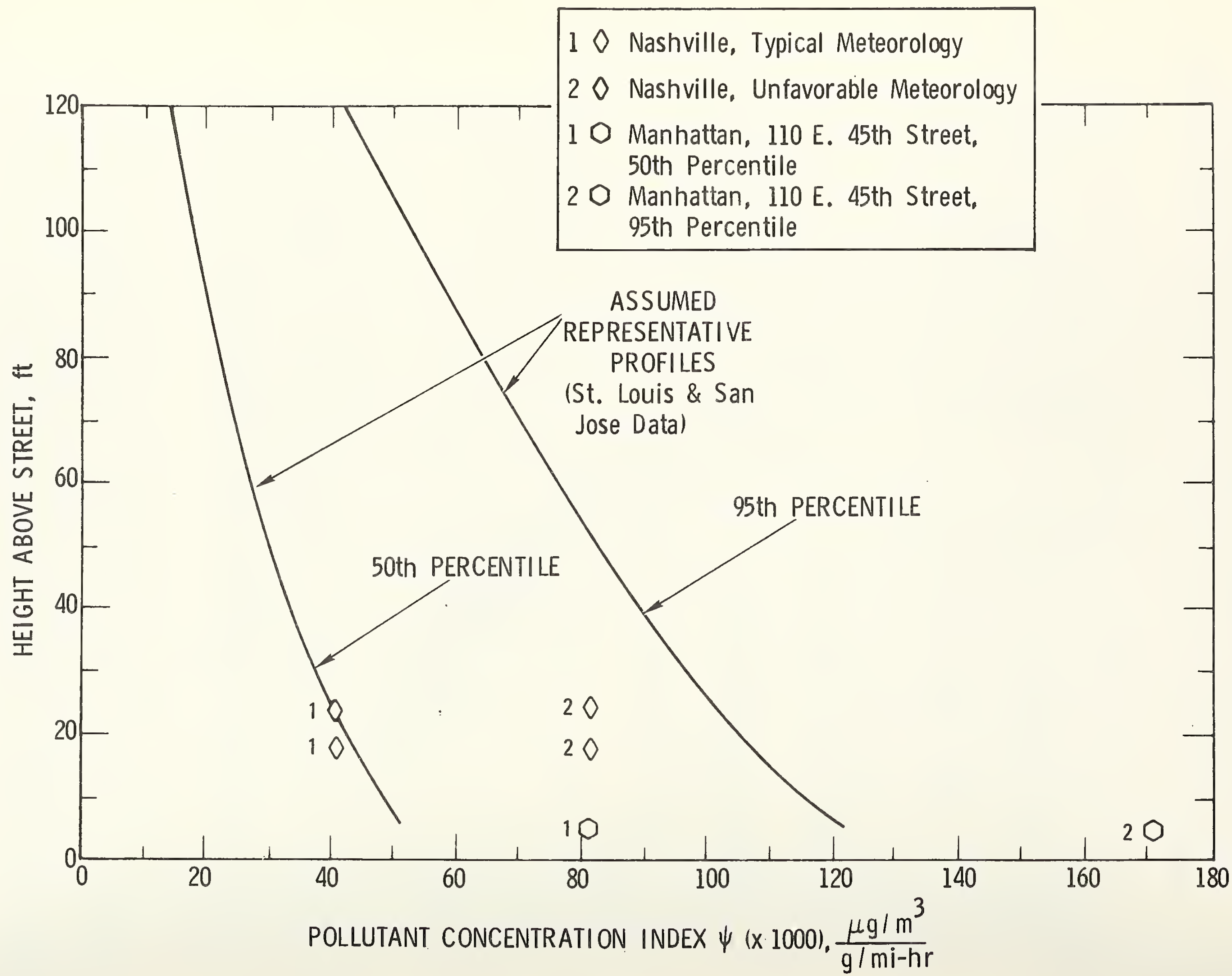

Figure 3-4. Comparison of ψ Characteristics for Different Data Bases

45th Street and the traffic rate on nearby Lexington Avenue (Park Avenue, the opposite flanking street, is elevated at this point and is assumed not to make a substantial contribution to the probe reading). The traffic data was obtained from the New York City Department of Traffic (Ref. 3-29).

These two data points in Figure 3-4 lie well to the right of the generalized street canyon curves. This is considered to be a directionally correct trend, since the Manhattan building-structure/traffic-flow complex very likely represents a worst-case combination of street canyon factors.

This study uses both the generalized 50th-percentile curve and the 50th-percentile Manhattan data point as the basis for projecting LDV dieselization effects. Results derived from the 50th-percentile curve are taken to represent frequently recurring conditions applicable to any urban area CBD, while results derived from the Manhattan data base are considered to represent recurring effects in a worst-case metropolitan geometry.

Particulate concentrations based on the 50th-percentile generalized curve were calculated from

$$\text{conc} = \psi_{50} \times \text{EF} \times \text{TC}$$

where

conc = particulate concentration, $\mu g/m^3$

ψ_{50} = 50th-percentile value of ψ at the appropriate height (from Figure 3-3)

EF = particulate emission factor applicable to the analysis case (Manhattan statistics), g/veh-mi

TC = traffic count in the street canyon, veh/hr

Particulate concentrations based on the Manhattan data were calculated from the relation given in Appendix C.

3.4 PARKING GARAGE

3.4.1 Methodology

A suitable data base for an empirical treatment of the enclosed parking garage could not be found. Therefore, the problem was treated on an analytical basis, considering a closed, ventilated chamber in which pollutant emissions and ventilation air are assumed to be completely mixed in the chamber atmosphere. For these conditions, the general equation for the concentration of pollutant may be written as

$$C = C_a + \frac{N}{q}\left[fG_d + (1 - f)G_g\right]\left[1 - e^{-qt/V}\right] + (C_o - C_a)e^{-qt/V} \tag{1}$$

where

- C = concentration of pollutant in garage at any time t
- C_a = concentration of pollutant in incoming ventilation air = ambient
- C_o = initial concentration of pollutant in garage
- N = number of active cars in the garage
- q = volume rate of incoming ventilation air, or capacity of ventilation system
- f = fraction of active cars in garage that are diesels
- G_d = emission rate per unit time per diesel car
- G_g = emission rate per unit time per gasoline car
- V = volume of garage .

This relationship may be shown to be identical to other published forms of the general equation, such as given by Turk (Ref. 3-7).

The analysis was restricted to passenger cars (Manhattan fleet statistics) and considered two driving modes within the garage: idle (including startup effects), and driving in low gear. The exhaust particulate contribution of each mode was estimated for diesel- and gasoline-powered cars, and composite emission rates were determined in accordance with an assumed split between the average duration of "idle" and "drive" modes. On the basis of a brief survey of representative Los Angeles garages, relationships were established among garage volume, parking capacity, and average number of vehicles active at any time. These relationships permit a parametric solution to Equation (1) in which the particulate concentration of the garage air is expressed in terms of the specific ventilation rate (q/V) and the activity mode of vehicles within the garage.

Analyses were performed for the case of normal off-peak vehicle turnover, and for an overload situation, such as an evening departure rush, when the garage exit facilities become temporarily overloaded. In addition, a worst-case analysis was performed for the case of an unventilated garage in a complete calm. Effects for various projection years were examined.

3.4.2 Data Base and Analysis Techniques

The available data base pertaining to idle particulate emissions is very limited, and a number of assumptions and approximations were made to establish appropriate values for the various projection years examined.

Particulate emission rates at idle for diesel-powered cars were obtained from EPA data (Ref. 3-30) based on measurements made in a study by Southwest Research Institute. The data were limited to measurements on a Mercedes 240D and a Volkswagen diesel Rabbit at hot idle conditions. Following a suggestion by EPA (Ref. 3-30), the data were adjusted for cold conditions using the ratio of FTP bag 1 (cold start) to bag 3 (hot start) particulate emission factors. This produced an average value of 3 g/hr, which was taken to be representative of baseline (1975) vehicle conditions.

No data were found for the particulate emission rate at idle for gasoline-powered cars. For the baseline case, this quantity was scaled from the diesel idle emission rate in proportion to gasoline/diesel idle fuel consumption (mass basis) and LDV gasoline/diesel composite emission factors developed in the Manhattan areawide analysis.

The idle fuel consumption rate for gasoline cars was developed from Reference 3-31, an EPA document which reports a sales-weighted value of

0.82 gal/hr for model years 1972-1974. Based on data given in this document and allowing for an expected reduction in engine displacement for future model year cars, an idle fuel consumption rate of 0.57 gal/hr was calculated. This value was assumed to apply to all scenario conditions examined in this study.

The idle fuel consumption rate for diesel cars was developed from EPA studies reporting idle fuel consumption rates of from 0.11 to 0.26 gal/hr for various diesel cars (Refs. 3-30, 3-31). An average value of 0.2 gal/hr was adopted for use.

Particulate emission rates specific to the garage "drive" mode also required a number of assumptions and approximations. For the baseline case, the particulate emission rate in drive was scaled from the baseline idle mode rate using the ratio of volumetric exhaust flow rate, drive to idle. This procedure implicitly assumes that the particulate concentration in the exhaust is equal for the two modes.

Exhaust volumetric flow rates for diesel cars were estimated from Reference 3-32, which provides data for four diesel passenger cars as measured over the 13-mode test procedure. This test covers the idle mode plus 10 conditions of varying load at two speeds. Mode 4 (intermediate speed, 50-percent load) was selected as being the test condition most closely approximating typical garage maneuvers such as a fairly brisk low gear acceleration, or driving up an inclined ramp of a multilevel garage. The data of Reference 3-32 indicate average values for exhaust flow rates for the diesel cars tested of 0.84 and 2.34 m^3/min in idle and in Mode 4, respectively. Accordingly, the particulate emission rate for diesel cars in the garage drive mode was calculated for the baseline case as

$$3 \times \frac{2.34}{0.84} = 8.4 \text{ g/hr}$$

This same ratio of exhaust flow rates was applied to gasoline cars.

With the baseline year values established as described above, it was necessary to estimate particulate emission rates for projection year vehicles. For gasoline cars, the dominant influence on particulates is the shift to unleaded fuel, starting with the 1975 model year, which results in a large decrease in the particulate emission rate. This effect may be assumed to apply to all driving modes. Accordingly, both the idle and drive mode emission rates for future gasoline cars were scaled from the baseline values in proportion to the composite emission factors developed in the Manhattan dump calculation (see also Table 3-2). In general, these factors vary with projection year and the assumed rate of LDV dieselization. For future years, which are of most concern to the garage problem, the contribution of gasoline cars becomes small in relation to that of diesel cars.

Given the uncertainties in predicting future control methodology, it cannot be assumed arbitrarily that control measures which may be implemented to reduce the particulate emissions of diesel cars for FTP certification will also be effective at the idle condition. Therefore, this study conservatively assumes no reduction in the idle rate of diesel particulates for future years. In contrast, it was considered that the garage <u>driving</u> mode emissions would reflect FTP control measures, and these emissions were scaled in proportion to composite emission factors for the appropriate projection years.

The effects of diesel vehicles operating in both the idle and drive modes may be expressed in terms of a combined emission factor as

$$G_d = G_{idle,d} \cdot X_{idle} + G_{drive,d} \cdot X_{drive}$$

where X_{idle} and X_{drive} are the average values of the fraction of total active time within the garage which is spent in idle and drive modes, respectively. A similar equation may be written for G_g, the combined emission rate for gasoline cars.

This report assumes $X_{idle} = 0.25$ and $X_{drive} = 0.75$ during normal garage operations. This assumption probably understates the fraction of idle time which occurs in a single-level garage during off-peak times, when driving time within the garage may be very brief. The split assumed here reflects cases such as multilevel garages, where driving time within the garage becomes more significant. Reverse conditions may apply for a garage serving a large office in which the exit facilities become temporarily overloaded at close of the business day. In a facility of this type, a very high fraction of vehicle active time would be spent at idle. This situation is examined as a special case.

The fraction of cars in the garage that are diesels (f in Equation 1) was assumed to equal the fraction of LDV VMT which is accumulated by diesel cars. The diesel VMT fraction is developed as described in Sections 2.2 and 2.3 (see Table 2-17).

For convenience in relating Equation 1 to observed garage parameters, the term N/q was expressed and utilized in the calculations as

$$\frac{Y \ Ncap/V}{(q/V)}$$

where Y is defined as the ratio of the number of active vehicles N to the garage parking capacity Ncap. Based on measurements made of an enclosed garage in Los Angeles, assumed to be typical, Ncap/V was established as 0.012 veh/m^3.

Observations of off-peak activity in several garages, including the high-traffic multilevel parking garage at Los Angeles International Airport, indicated that a vehicle capacity fraction Y of about 0.75 percent would be a conservatively high representation of off-peak activity for many types of garages, while a Y-value of about 1.5 percent would be an approximate upper bound for a very busy garage. In a garage having a 150-vehicle capacity, these Y-values correspond approximately to an average of one and two vehicles, respectively, in continuous, active operation.

When the garage exit facilities become temporarily overloaded, a queue of idling cars develops. This could occur, for example, in the evening rush period for a garage serving a large office complex. This type of episode was modeled in the present study by assuming that a number of vehicles, equal on the average to 25 percent of the garage parking capacity, are idling for a period of 15 minutes within the garage.

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4. COMPUTATIONAL RESULTS

4.1 GENERAL URBAN AREA RESULTS

Following the methods outlined in Section 2, the pollutant dumps for HC, CO, NO_x, particulates and BaP were calculated for Manhattan, St. Louis, and Phoenix at the four time points and the three LDV dieselization rates selected for study. The special case of the Manhattan taxi fleet dieselization was examined with respect to particulate and BaP emissions under the conditions of a 25-percent dieselization rate applied to the Manhattan passenger car fleet. The rationale, computational approach, and results for this case are discussed in Section 4.1.1.2.

Numerical results for the base case, 10-percent, and 25-percent dieselization scenarios are tabulated in Appendix D. Plots of the results are presented in this section. These are arranged, for each metropolitan area, so that the dump results for individual vehicle classes appear first, followed by successively larger aggregations of source contributions to the total dump. For convenience in locating individual plots in this series, Table 4-1 identifies the plots by figure number and page.

4.1.1 Manhattan

4.1.1.1 Base Case, 10-Percent, and 25-Percent Scenarios

Results of the pollutant dump calculation for Manhattan are shown graphically in Figures 4-1 through 4-12.

Referring first to mobile source particulate effects, the dump contributions by LDV's are shown in Figure 4-1 (left), indicating, for the 10- and 25-percent scenarios, a rapid rise in the dump in the 1975-1985 period (the curves in this interval were shaped to reflect the dieselization rate profile shown in Figure 2-1). Characteristically, a change in curvature takes place starting in late 1984 as new, more stringently controlled (0.25 g/mi) vehicles begin to enter the fleet. Characteristically also, the curves flatten out rapidly after 1985 when the production of new LDVD's is held constant at the

Table 4-1. Display of Graphical Results for Areawide Pollutant Dump

Pollutant/Source	Manhattan		St. Louis		Phoenix	
	Figure	Page	Figure	Page	Figure	Page
<u>Particulates</u>						
LDVD	4-1	4-5	4-15	4-27	4-27	4-40
LDTD	4-1	4-5	4-15	4-27	4-27	4-40
HDVD	4-1	4-5	4-15	4-27	4-27	4-40
Total Diesel[a]	4-2	4-6	4-16	4-28	4-28	4-41
Total Gasoline[b]	4-2	4-6	4-16	4-28	4-28	4-41
Total Mobile Sources[c]	4-2	4-6	4-16	4-28	4-28	4-41
Stationary Sources	4-11	4-15	4-25	4-38	4-37	4-50
Mobile plus Stationary Sources	4-12	4-16	4-26	4-39	4-38	4-51
<u>BaP</u>						
LDVD	4-3	4-7	4-17	4-29	4-29	4-42
LDTD	4-3	4-7	4-17	4-29	4-29	4-42
HDVD	4-3	4-7	4-17	4-29	4-29	4-42
Total Diesel[a]	4-4	4-8	4-18	4-30	4-30	4-43
Total Gasoline[b]	4-4	4-8	4-18	4-30	4-30	4-43
Total Mobile Sources[c]	4-4	4-8	4-18	4-30	4-30	4-43
<u>HC</u>						
LDVD	4-5	4-9	4-19	4-31	4-31	4-44
LDTD	4-5	4-9	4-19	4-31	4-31	4-44

[a] LDVD + LDTD + HDVD
[b] LDVG + LDTG + HDVG
[c] Diesel + Gasoline

Table 4-1. Display of Graphical Results for Areawide Pollutant Dump (cont'd)

Pollutant/Source	Manhattan		St. Louis		Phoenix	
	Figure	Page	Figure	Page	Figure	Page
HC (Cont'd)						
HDVD	4-5	4-9	4-19	4-31	4-31	4-44
Total Diesel[a]	4-6	4-10	4-20	4-32	4-32	4-45
Total Gasoline[b]	4-6	4-10	4-20	4-32	4-32	4-45
Total Mobile Sources[c]	4-6	4-10	4-20	4-32	4-32	4-45
Stationary Sources	4-11	4-15	4-25	4-38	4-37	4-50
Mobile plus Stationary Source	4-12	4-16	4-26	4-39	4-38	4-51
CO						
LDVD	4-7	4-11	4-21	4-33	4-33	4-46
LDTD	4-7	4-11	4-21	4-33	4-33	4-46
HDVD	4-7	4-11	4-21	4-33	4-33	4-46
Total Diesel[a]	4-8	4-12	4-22	4-34	4-34	4-47
Total Gasoline[b]	4-8	4-12	4-22	4-34	4-34	4-47
Total Mobile Sources[c]	4-8	4-12	4-22	4-34	4-34	4-47
Stationary Sources	4-11	4-15	4-25	4-38	4-37	4-50
Mobile plus Stationary Sources	4-12	4-16	4-26	4-39	4-38	4-51
NO_x						
LDVD	4-9	4-13	4-23	4-35	4-35	4-48
LDTD	4-9	4-13	4-23	4-35	4-35	4-48
HDVD	4-9	4-13	4-23	4-35	4-35	4-48
Total Diesel[a]	4-10	4-14	4-24	4-36	4-36	4-49

[a] LDVD + LDTD + HDVD
[b] LDVG + LDTG + HDVG
[c] Diesel + Gasoline

Table 4-1. Display of Graphical Results for Areawide Pollutant Dump (cont'd)

Pollutant/Source	Manhattan		St. Louis		Phoenix	
	Figure	Page	Figure	Page	Figure	Page
NO_x (Cont'd)						
Total Gasoline[b]	4-10	4-14	4-24	4-36	4-36	4-49
Total Mobile Sources[c]	4-10	4-14	4-24	4-36	4-36	4-49
Stationary Sources	4-11	4-15	4-25	4-38	4-37	4-50
Mobile plus Stationary Sources	4-12	4-16	4-26	4-39	4-38	4-51

[a]LDVD + LDTD + HDVD
[b]LDVG + LDTG + HDVG
[c]Diesel + Gasoline

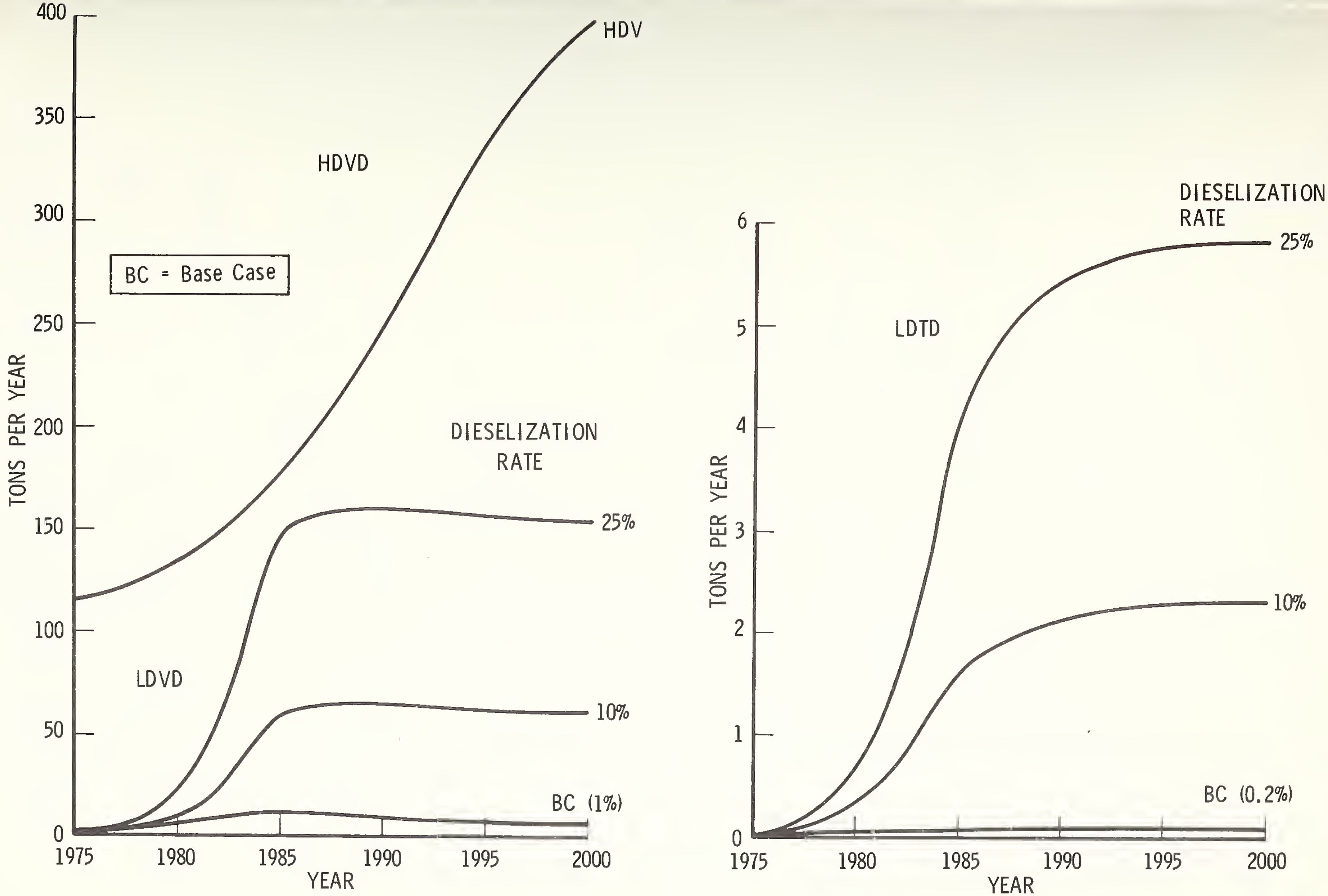

Figure 4-1. Manhattan Particulate Dump -- Diesel LDV, HDV, and LDT Exhaust Emission Contributions

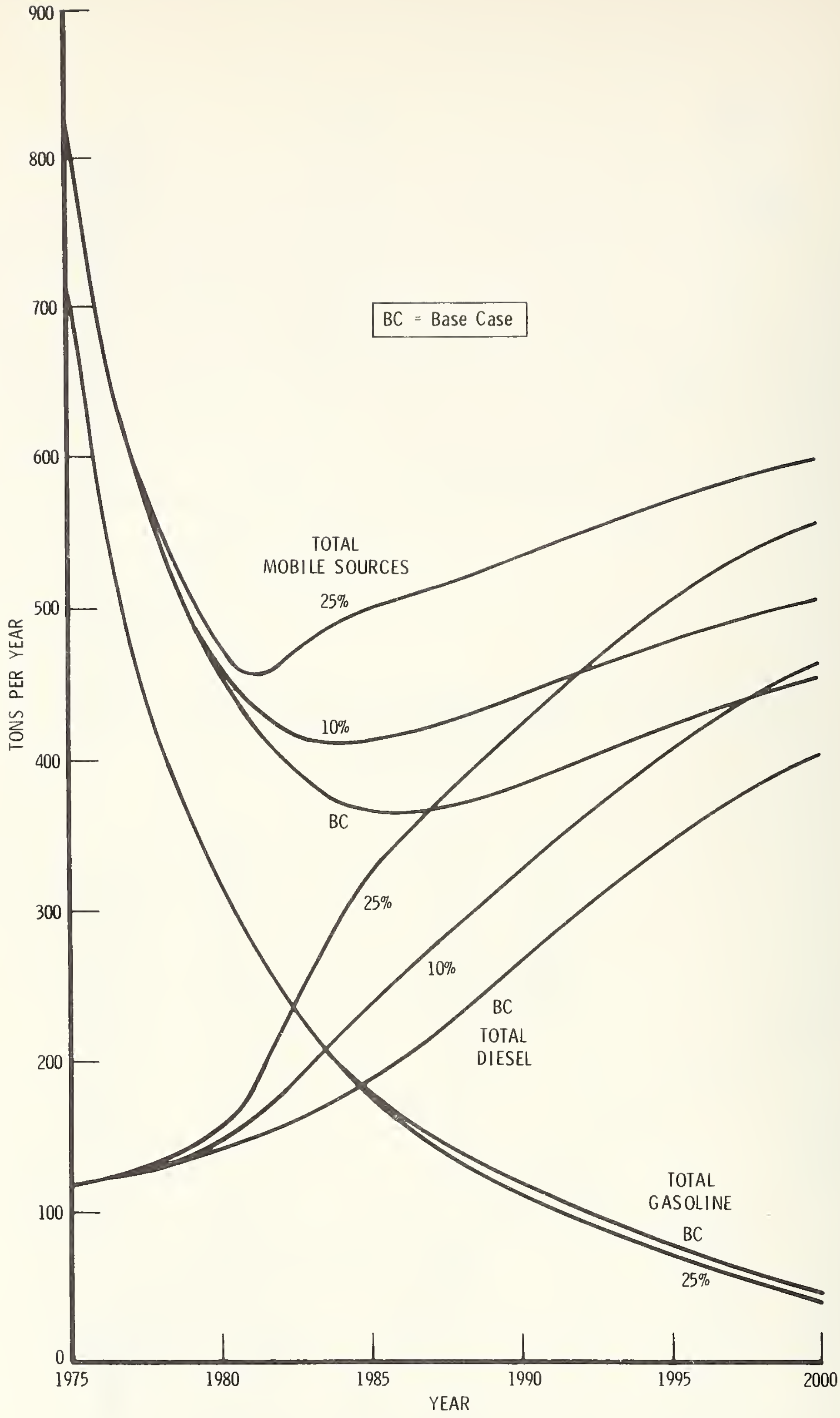

Figure 4-2. Manhattan Particulate Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

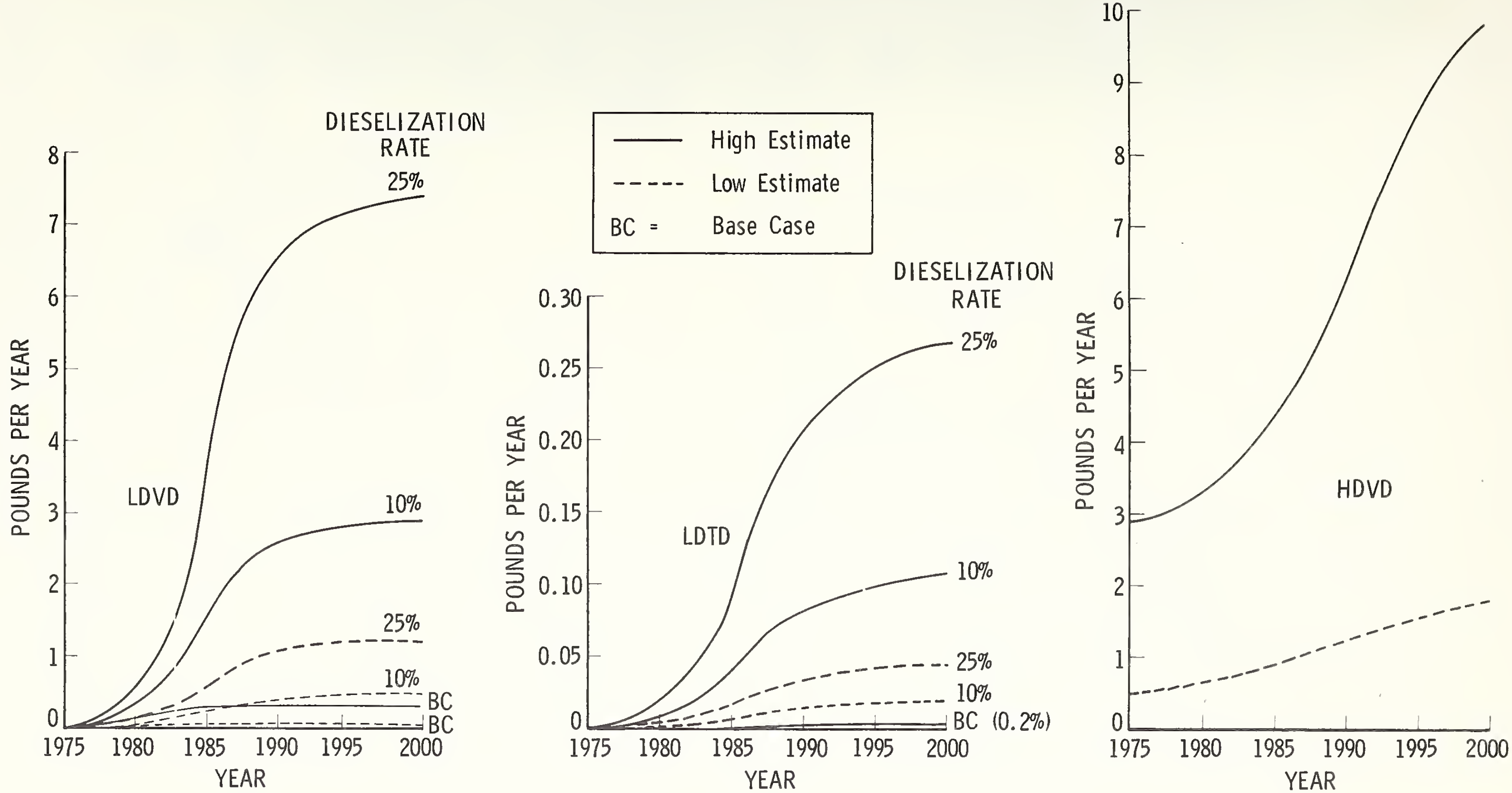

Figure 4-3. Manhattan BaP Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

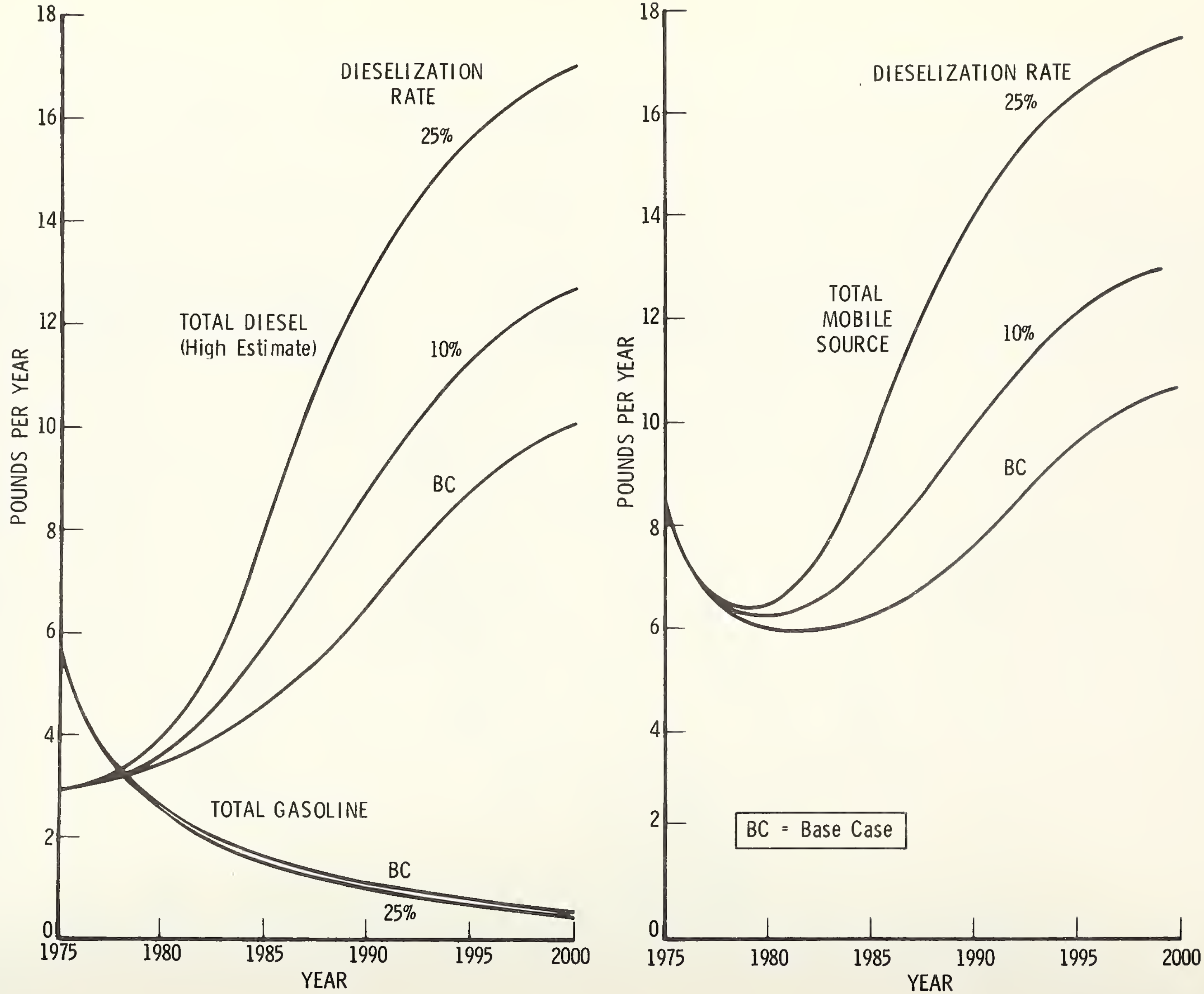

Figure 4-4. Manhattan BaP Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

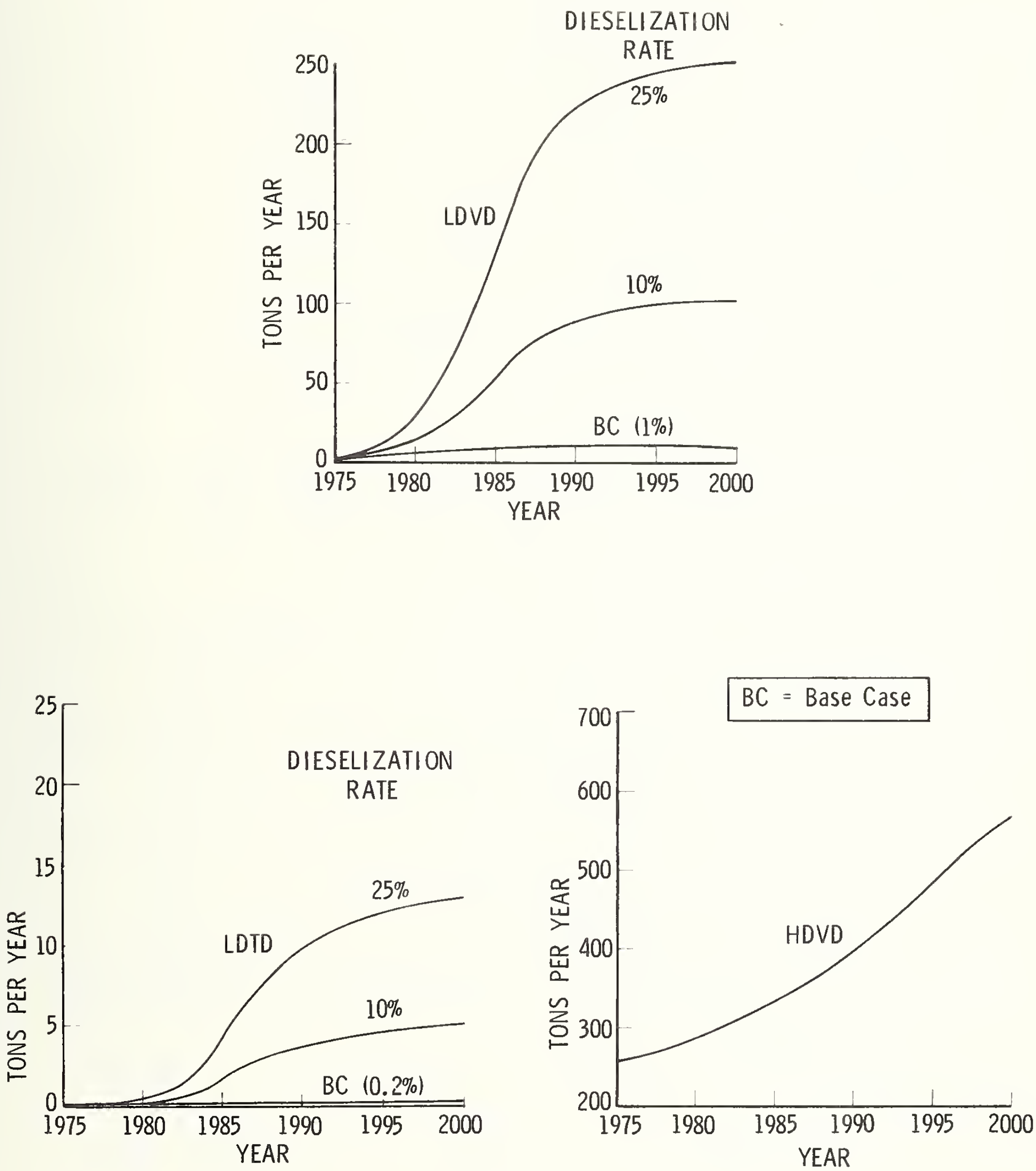

Figure 4-5. Manhattan HC Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

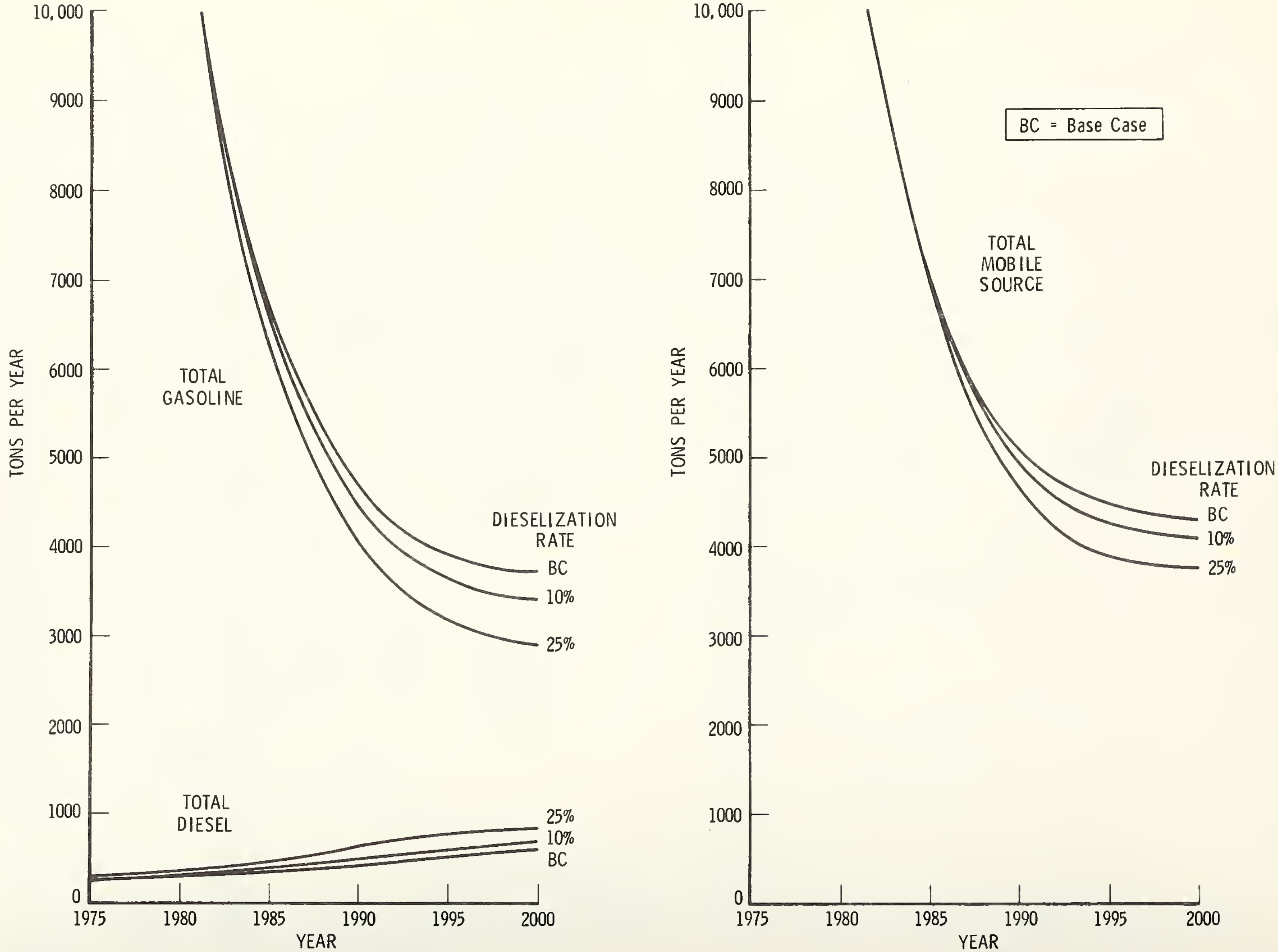

Figure 4-6. Manhattan HC Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust and Evaporative/Crankcase Emission Contributions

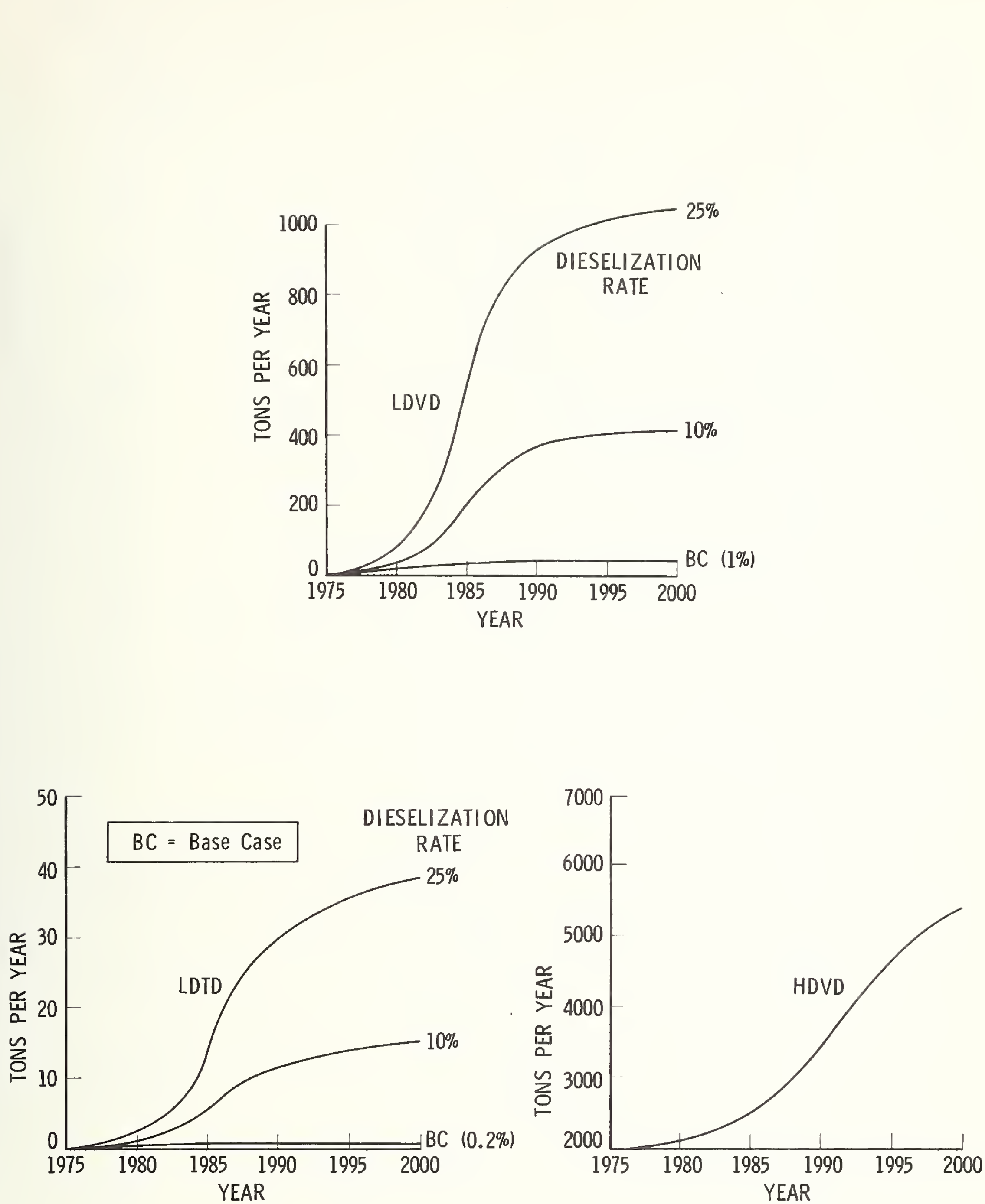

Figure 4-7. Manhattan CO Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

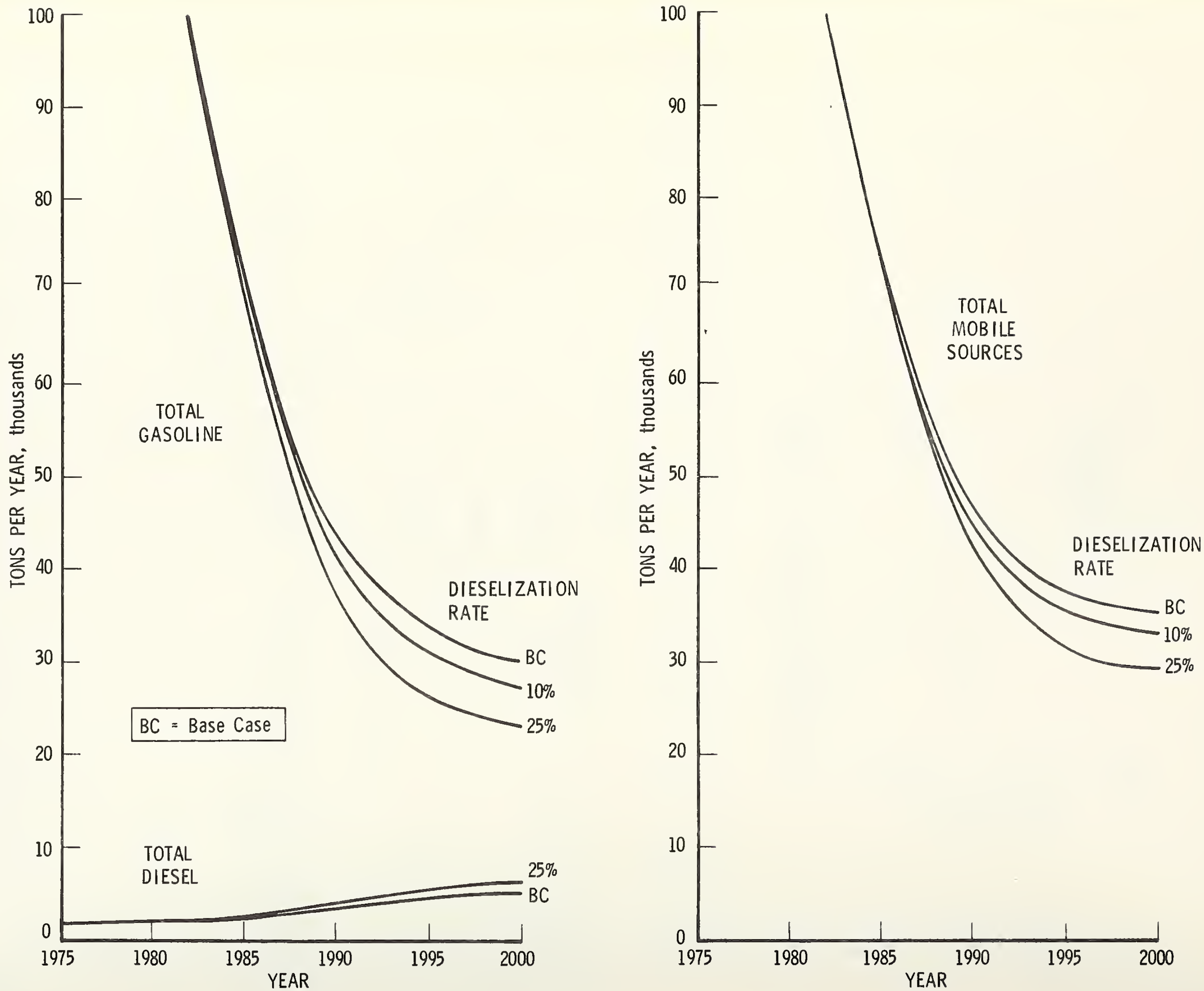

Figure 4-8. Manhattan CO Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

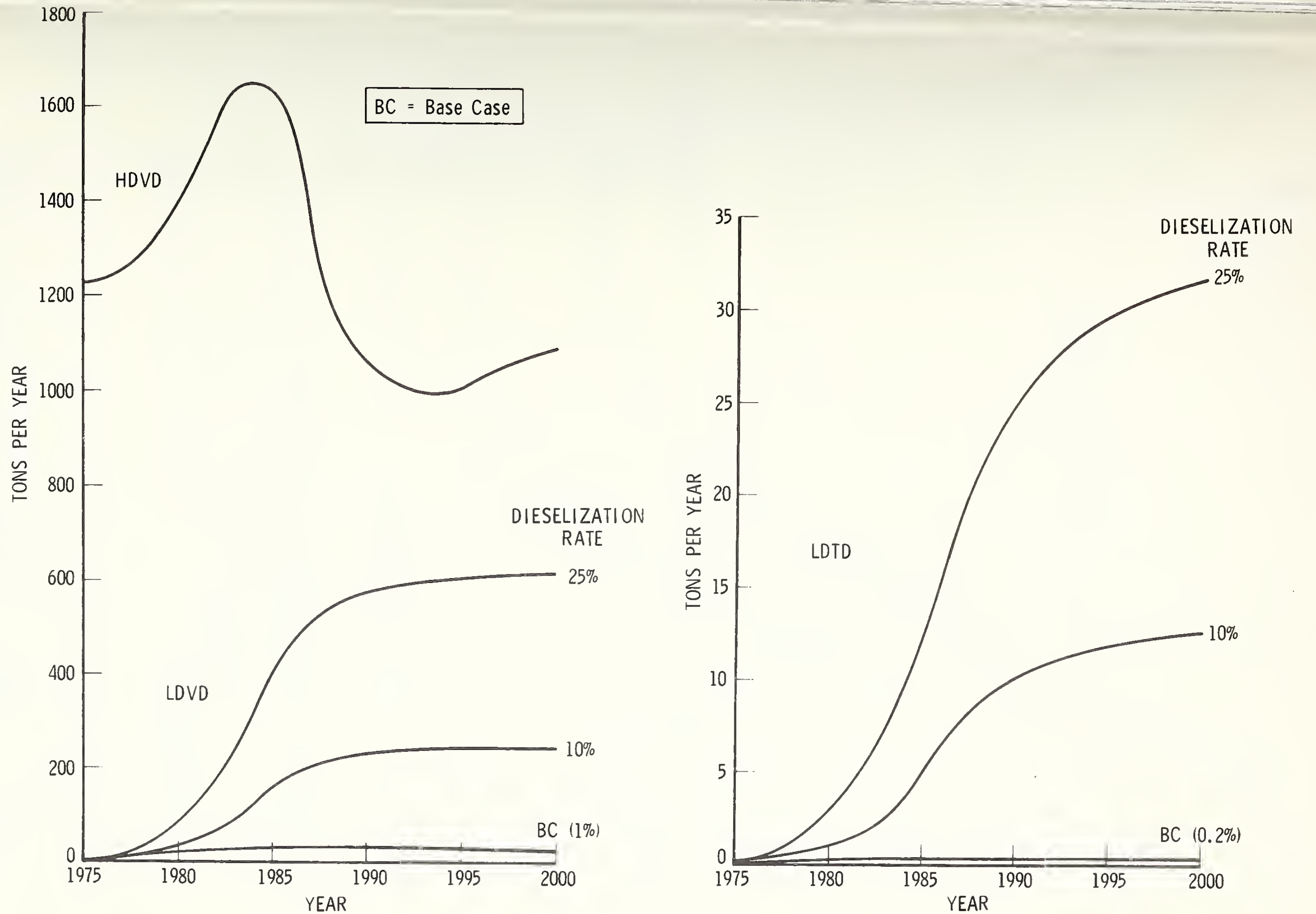

Figure 4-9. Manhattan NO_x Dump -- Diesel LDV, HDV, and LDT Exhaust Emission Contributions

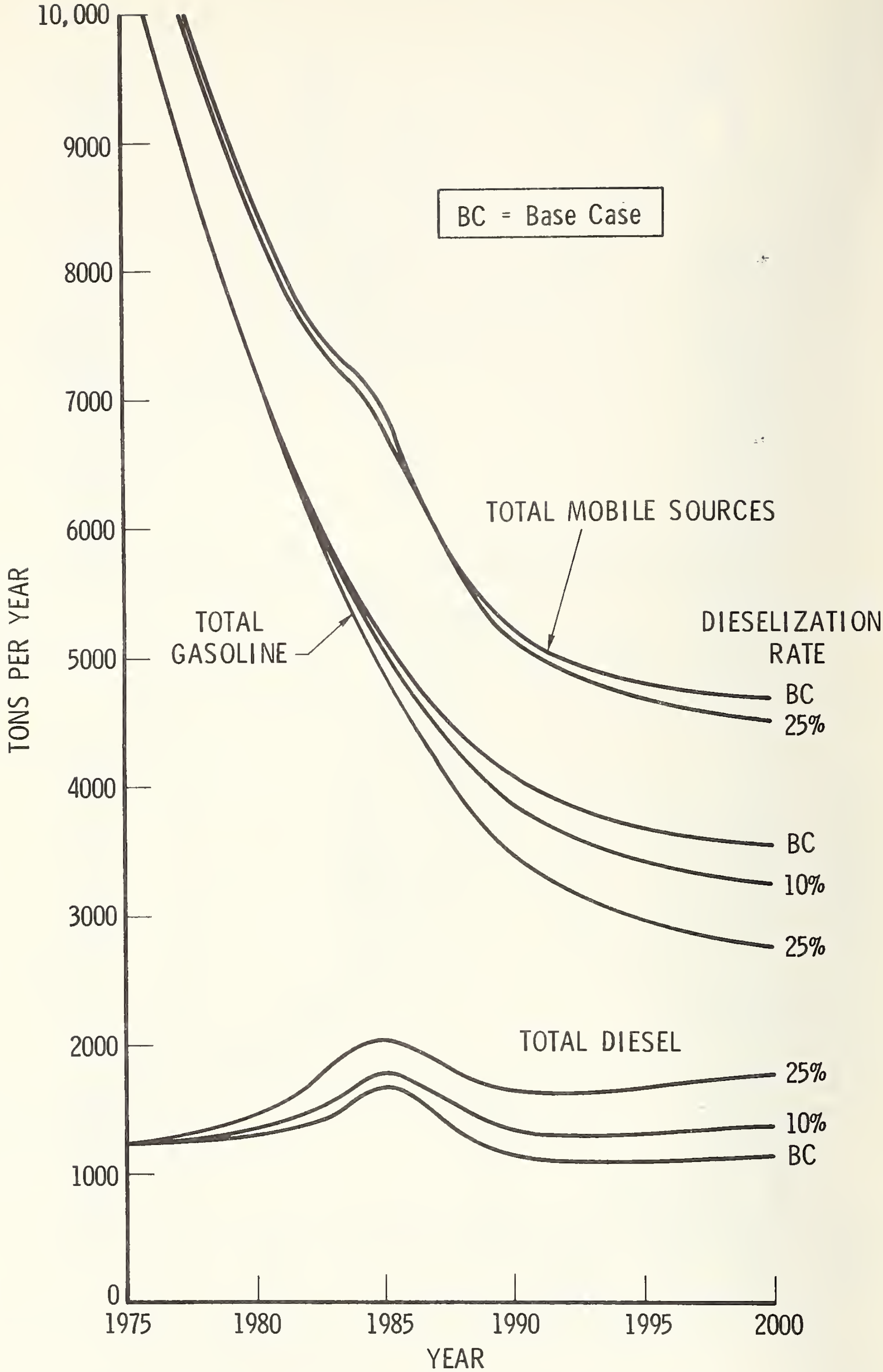

Figure 4-10. Manhattan NO_x Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

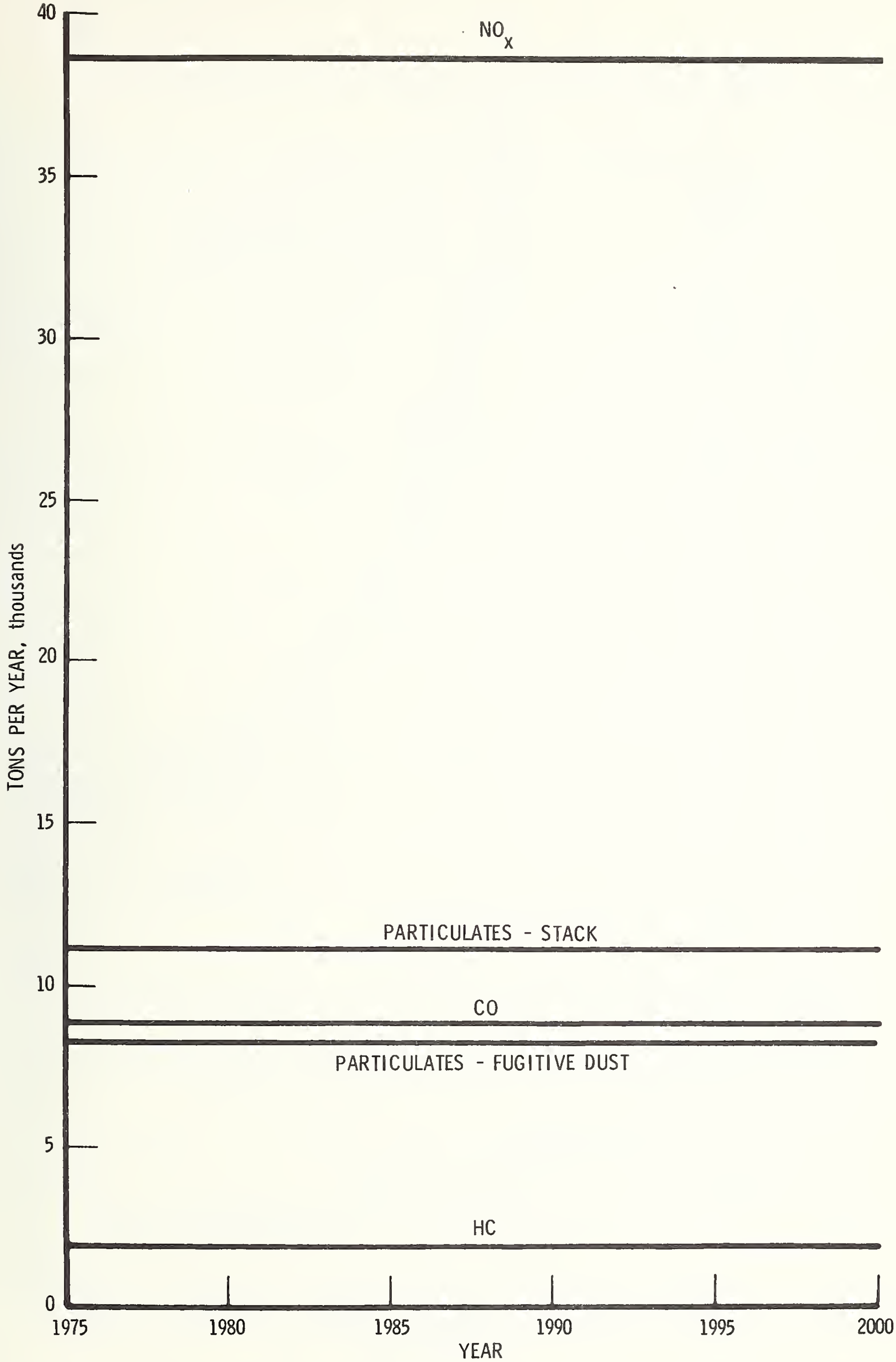

Figure 4-11. Manhattan Pollutant Dump -- Stationary Source Contributions

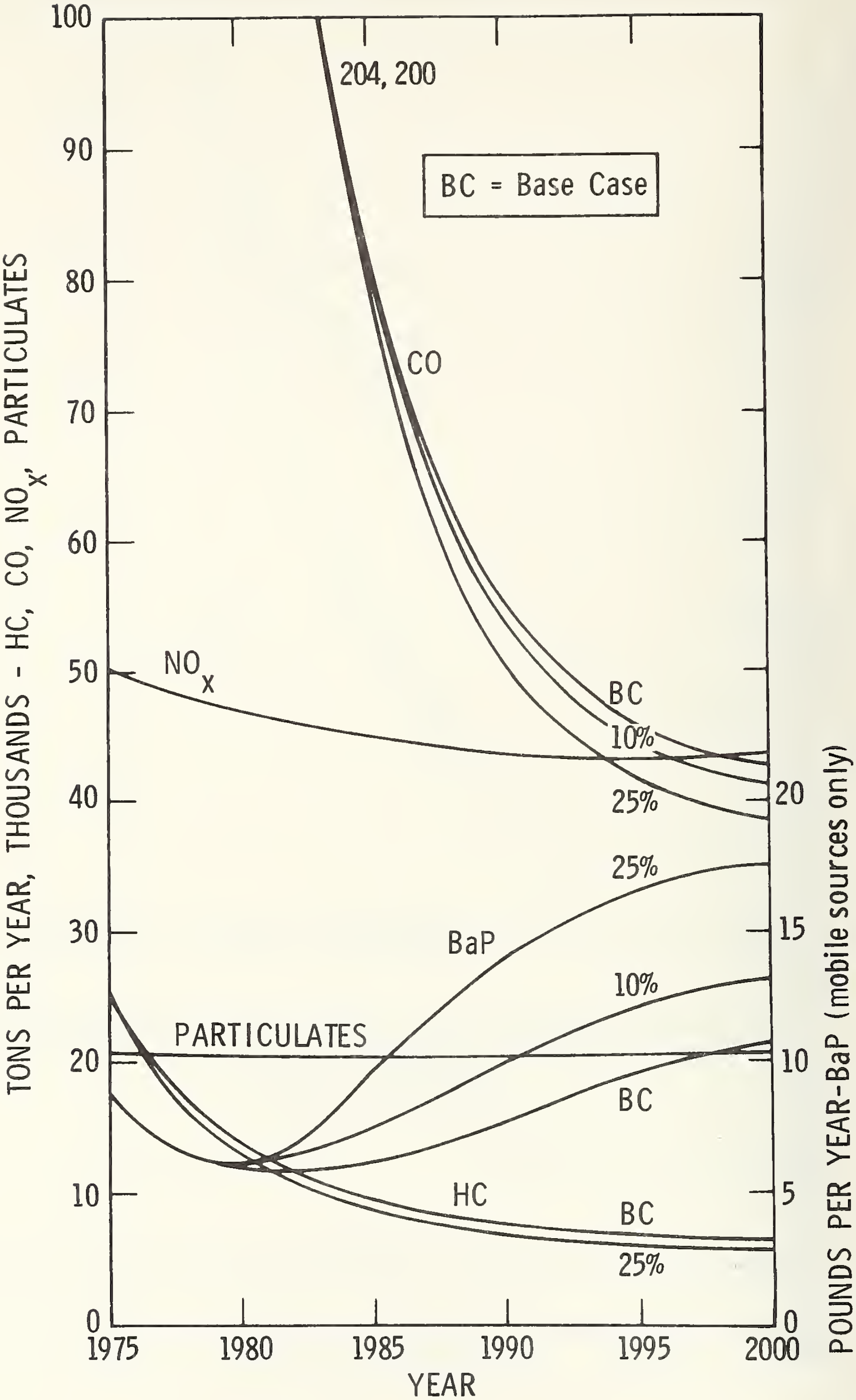

Figure 4-12. Manhattan Pollutant Dump -- Mobile Plus Stationary Source Contributions

assumed maximum dieselization rate. The levelling of the dump curve is particularly rapid for Manhattan, because VMT is taken to be fixed at the 1975 level. As indicated, the curves reach a peak (at about 1990 in the 25-percent case) and then gradually decline as new vehicles displace old ones. The curves assume a constant level in the year 2005 when the LDVD fleet consists wholly of 0.25 g/mi vehicles. In the year 2000, the dump for the 25-percent dieselization case is about 155 tons per year.

The curve shapes for the LDTD particulate dumps, also shown in Figure 4-1 (right), are slightly different from those for the LDVD. One effect, it must be noted, is the influence of the plot scale, which is greatly expanded relative to the LDVD plot. Apart from this, the curvature of the 10-percent and 25-percent curves in the post-1985 period is reduced, reflecting two factors which are different for the LDTD class: (1) the fraction-in-use characteristic (LDT's contain a larger fraction of older vehicles; see Table 2-4) and (2) the emission rate of older vehicles (higher for the uncontrolled 6001 - 8500# vehicles; see Table 2-13). These influences cause the LDTD dump to peak later than the LDVD; that is, roughly in the year 2000. At this point, the dump rate for the 25-percent dieselization case is 5.8 tons per year. This much smaller magnitude of dump relative to LDVD largely reflects a low use rate (VMT) for this vehicle class (see Table 2-7).

The HDVD particulate dump is included in Figure 4-1 (left). Only one characteristic is shown because a single projection was adopted for study. The curve shape is a direct reflection of the diesel fraction as projected in Figure 2-5, since the emission rate for this class is taken to be constant (at the uncontrolled level of 2.0 g/mi). The dump characteristic continues to rise after the year 2000, as a result of continued increase in the fleet fraction of diesel vehicles, and begins to level off in the year 2005. At the 2000 time point, the dump rate is about 400 tons per year, or greater than 2.5 times that of LDVD's in the maximum or 25-percent dieselization case.

The influence of the HDVD particulate dump is reflected in the shape of the curves for total diesel vehicle particulate dump (LDVD + LDTD + HDVD) shown in Figure 4-2. Shown also in the figure is the total dump for gasoline vehicles. The gasoline curves decline rapidly with projection year as a result of the replacement of older LDV's and LDT's by catalyst-equipped vehicles with substantially lower emission levels (see Tables 2-8, 2-10). Note that a higher rate of LDV dieselization reduces the gasoline particulate dump, as would be expected, since the introduction of a greater number of new diesel vehicles in the fleet would be accompanied by a corresponding reduction in the gasoline component.

Total diesel and total gasoline emissions are combined in the Figure 4-2 plot labeled Total Mobile Sources. The particulate dump in the early years is dominated by the declining gasoline characteristic and begins to rise again in the 1980 to 1985 time period under the influence of an increasing diesel vehicle population. The total particulate dump from mobile sources peaks in the period 2000 - 2005, reaching a level of about 600 tons per year for the 25-percent dieselization case.

Mobile source BaP effects for Manhattan are displayed in Figures 4-3 and 4-4. The LDVD contribution, shown in Figure 4-3 (left), is given for two possible levels of BaP emission rate (see Table 2-9). The curves exhibit characteristics similar to the particulate effects shown in Figure 4-1, but with reduced curvature in the post-1985 period because BaP emissions are taken to be uncontrolled and constant. The curve-flattening effect of new vehicle controls indicated for particulates, therefore, is absent in the case of BaP. The dump in the year 2000 is about 7.4 lb/yr for the 25-percent high BaP emission rate case.

The BaP dump for LDTD's is shown in Figure 4-3 (center). The dump magnitudes are small, roughly 4 percent of the LDVD dump or 0.27 pounds per year in the 25-percent case. The HDVD BaP dump, shown in Figure 4-3 (right) is drawn for both a low and a high estimate of emission rate (see Table 2-15). The curve characteristics are similar to those for HDVD particulates and, likewise, are a direct reflection of the diesel fraction projection given in Figure 2-5. The maximum BaP dump is projected to occur at or near the year 2005; a level of about 9.8 pounds per year is indicated for the year 2000.

Total diesel and total gasoline BaP dumps are given in Figure 4-4 (left) for the high estimate of diesel BaP emission rate. The declining characteristics shown for gasoline reflects the replacement of older LDV's and LDT's in the fleet by catalyst-equipped vehicles with substantially lower BaP emission rate (see Tables 2-8, 2-10). The curve for total diesel BaP is dominated by the HDVD contribution and shows a level of about 17 pounds per year for the 25-percent dieselization case in the year 2000.

The total gasoline BaP dump added to the total diesel BaP dump produces the curves of Figure 4-4 (right), showing that the total mobile source BaP dump initially decreases and then rises steeply as the diesel vehicle contribution increases in later years. In the year 2000 the dump is about 17.5 pounds per year at the 25-percent dieselization rate.

Mobile source HC effects for Manhattan are displayed in Figures 4-5 and 4-6. The HC dumps for LDVD's and LDTD's are shown in Figure 4-5 (top and left). The LDVD curves are generally similar to those for BaP, since the emission rate, though variable, is not drastically changed in the interval examined (0.6 to 0.41 g/mi; see Table 2-9). The dump peaks in the year 2005 at a level of about 250 tons per year for the 25-percent case. The LDTD curves reflect a higher (constant) emission rate (see Tables 2-12, 2-13), but peak at a much lower level of about 13 tons per year due to VMT effects.

The HC dump for HDVD's is shown in Figure 4-5 (right). The curve shape is somewhat altered from particulates and BaP, since in this case emission control of new vehicles is introduced beginning in 1983 (see Table 2-15). The curve indicates a dump of 570 tons per year in 2000, or about twice the contribution of LDVD's at the 25-percent dieselization rate. The HDVD dump approaches a peak of about 600 tons per year in 2005.

The total diesel HC dump is shown in Figure 4-6 (left) in comparison with the total gasoline HC dump, which includes evaporative amd crankcase emissions as well as exhaust emissions. The declining gasoline characteristic primarily reflects the replacement of older LDV's and LDT's in the fleet by newer vehicles with catalytic converters that operate at lower HC emission rates (see Table 2-8). As indicated, the gasoline contribution is significantly larger than the diesel and, as expected, shows a decrease in dump with increasing dieselization rate.

The dominance of the HC contribution by gasoline vehicles is reflected in the curves of Figure 4-6 (right), showing the total mobile source HC dump, diesel and gasoline vehicles combined. The dump approaches a minimum in the year 2000. At this time, the dump at the 25-percent dieselization rate is about 3700 tons per year.

Mobile source CO effects for Manhattan are given in Figures 4-7 and 4-8. The LDVD, LDTD, and HDVD characteristics shown in Figure 4-7 are similar to the corresponding BaP curves, reflecting the influence of constant (or near-constant) emission rates throughout the time span. The LDVD and LDTD dumps peak in the year 2005 at levels of 1050 and 39 per year, respectively. The HDVD dump approaches a maximum in 2005, at which point the dump is 5400 tons per year.

Total diesel and total gasoline dumps for CO, shown in Figure 4-8 (left), exhibit characteristics similar to the corresponding curves for HC. The gasoline contribution dominates, also reflected in the curves of Figure 4-8 (right), showing the sum of total gasoline and total diesel contributions.

Mobile source NO_x effects for Manhattan are given in Figures 4-9 and 4-10. The LDVD characteristic (Figure 4-9, left) exhibits a relativity flat plateau, which is the consequence of a significantly reduced NO_x emission rate starting with 1985 model year vehicles (see Table 2-9). The LDT characteristic (Figure 4-9, right) does not have this shape because control measures for this class are less stringent (see Table 2-12, 2-13).

The HDV NO_x dump, included in Figure 4-9 (left), peaks in 1984 and then declines rapidly as a result of a 75-percent reduction in new vehicle emission rate starting in 1985 (see Table 2-15). The dump reaches a minimum in 1993-1994 and then begins to rise again under the influence of an increasing diesel fraction. A second peak is approached in 2005 as the fraction of diesel vehicles in the HDV fleet stabilizes. The dump in the year 2000 is about 1100 tons per year, considerably reduced from the first peak level of 1640 tons per year.

Total diesel, total gasoline, and total mobile source contributions to the Manhattan NO_x dump are shown in Figure 4-10. The total diesel dump characteristic is heavily influenced by the large HDVD contribution and consequently it peaks in the period near the HDVD maximum.

The total gasoline NO_x characteristic, which declines rapidly toward a minimum estimated to occur in about 2005, is largely influenced by control measures in the LDVG fleet. Table 2-8 shows that new car emission rates decrease from 2.42 to 0.29 g/mi in the period of interest.

The total mobile source characteristic reflects the shape and magnitude of the total gasoline curves. As with HC and CO, a reduction in dump level is indicated with increasing LDV dieselization rate. This effect is further discussed in Section 5.

Stationary source contributions to the Manhattan dump are shown in Figure 4-11. Consistent with the recommendations of the New York authorities, the characteristics are shown to be invariant with projection year. It will be noted that the dump scale is expressed in thousands of tons per year, so that the levels indicated for particulates are an order of magnitude larger than those previously shown for mobile sources. Somewhat the reverse is indicated for HC and CO, while NO_x is several times larger than the mobile source levels. No BaP contribution is shown for the reason that reliable estimates of stationary source emissions for this specie could not be obtained.

The sums of mobile and stationary source contributions for Manhattan are shown in Figure 4-12. Since stationary source emissions are constant with time for Manhattan, the shapes indicated are totally the influence of mobile source effects. At the scales selected for plotting, LDV dieselization effects cannot be discerned in the case of NO_x and particulates.

4.1.1.2 Taxi Fleet Dieselization Scenario

This special analysis for Manhattan investigates the effects on particulates and BaP were the entire Manhattan taxi fleet to be dieselized.

Taxi dieselization was treated as an event that would be superimposed on the dieselization of passenger cars. Two rates of passenger car dieselization were considered: the 1-percent base case rate and the 25-percent rate. The conversion of the taxi fleet to diesel-powered vehicles was assumed to be complete by 1985; this assumption precluded the necessity of defining a schedule for the entry of new vehicles into the fleet. Since Manhattan taxi travel represents about 21 percent of the total LDV VMT (Ref. 4-1), the combined conditions of 100-percent taxi dieselization and 25-percent passenger car dieselization is equivalent in far term effects to dieselizing the general LDV population in Manhattan at a 40-percent rate.

As noted earlier, the pollutant dump calculation procedure is VMT-based and does not require that the absolute number of contributing vehicle sources be known. A breakdown of the Manhattan VMT into various fleet elements, including passenger cars and taxis (Ref. 4-1), was sufficient to isolate the passenger car and taxi contributions to the total LDV dump previously calculated for Manhattan. Having the Ming and Mind travel fraction quantities developed in the Manhattan dump calculation, it was possible to split the taxi and passenger car contributions into diesel and gasoline components for any of the LDV dieselization scenarios examined. The taxi dump for 100-percent taxi dieselization was scaled from the diesel-taxi dump component for the 25-percent dieselization scenario using the ratio: (total taxi VMT)/(diesel taxi VMT, 25-percent dieselization scenario).

The above procedure implicitly assumes that the distribution of taxis by model year is identical to the model year distribution of the Manhattan LDV fleet as a whole (see Table 2-4). For BaP, the model year distribution characteristic is of no consequence, since all LDV diesels emit BaP at the same (uncontrolled) rate. The issue relative to particulates, however, is that the postulated taxi fleet initially contains a large number of older vehicles which emit at a relatively high rate of 0.6 g/mi as compared to the 1985 rate of 0.25 g/mi (see Table 2-9). Accordingly, an alternate assumption for the model year composition of the taxi fleet was adopted, with a view toward bracketing the range of possible fleet composition conditions. This alternate assumption was that the taxi fleet wholly consists of 1985 and later model year diesel vehicles which emit at the lower controlled rate. Under this condition, the taxi dump is constant with time, and is obtained simply from the product: 0.25 x Total Taxi VMT. It may be noted that this alternate assumption may not be far from realistic, considering that the entire population of Fleet Medallion* cabs in New York City is turned over (renewed) every three years (Ref. 4-2).

The results of the taxi dieselization analysis for particulates are displayed in Figure 4-13. The left side of the figure shows the LDVD contribution to the particulate dump and the right side shows the sum of the LDVD and LDVG contributions. For clarity in these plots, the results obtained using the alternate assumption for the model year distribution of the taxi fleet are shown only for the 25-percent passenger car (PC) dieselization case. Thus, the plot at the left indicates that the total LDV dump (PC + taxis) would either (1) peak in 1985 at a level of 360 tons per year and then decay to a level of 245 tons in 2000 as new diesel vehicles replace older ones, or (2) in the alternate approach, peak in about 1990 at a level of 255 tons per year and then decay only slightly as new diesel vehicles enter the PC fleet. Likewise, the plot at the right, which shows the sum of the diesel and gasoline particulate dump, indicates a 1985 peak of either 400 tons per year or 280 tons per year in the case of the alternate assumption, both cases decaying to a level of 260 tons by the year 2000. These effects may be compared to the dump characteristic for the 25-percent LDV dieselization scenario, shown at the bottom of Figure 4-13 (right).

The impact of taxi dieselization on BaP is shown in Figure 4-14. As noted earlier, the model year fleet composition is of no consequence in the case of BaP, since all model years are assumed to emit at the same rate (see Tables 2-8 and 2-9). The plot at the right indicates that the dump approaches a maximum in the year 2000 at a level of about 12 pounds per year,

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*Medallion cabs are those which have purchased a license to cruise the streets. Nonmedallion cabs are restricted to answering calls for taxi service.

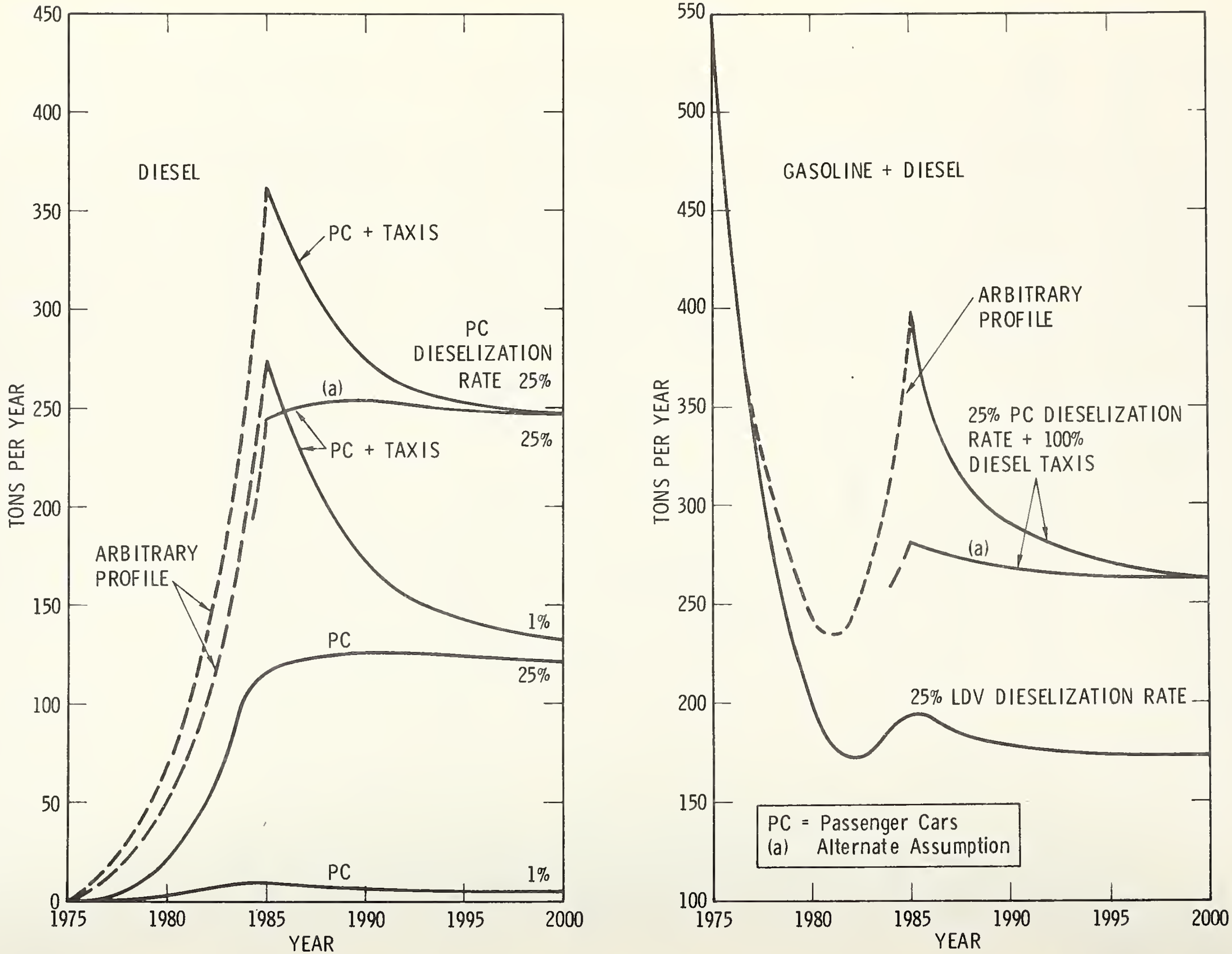

Figure 4-13. Manhattan 100-Percent Taxi Dieselization -- Diesel LDV and Total LDV Particulate Effects

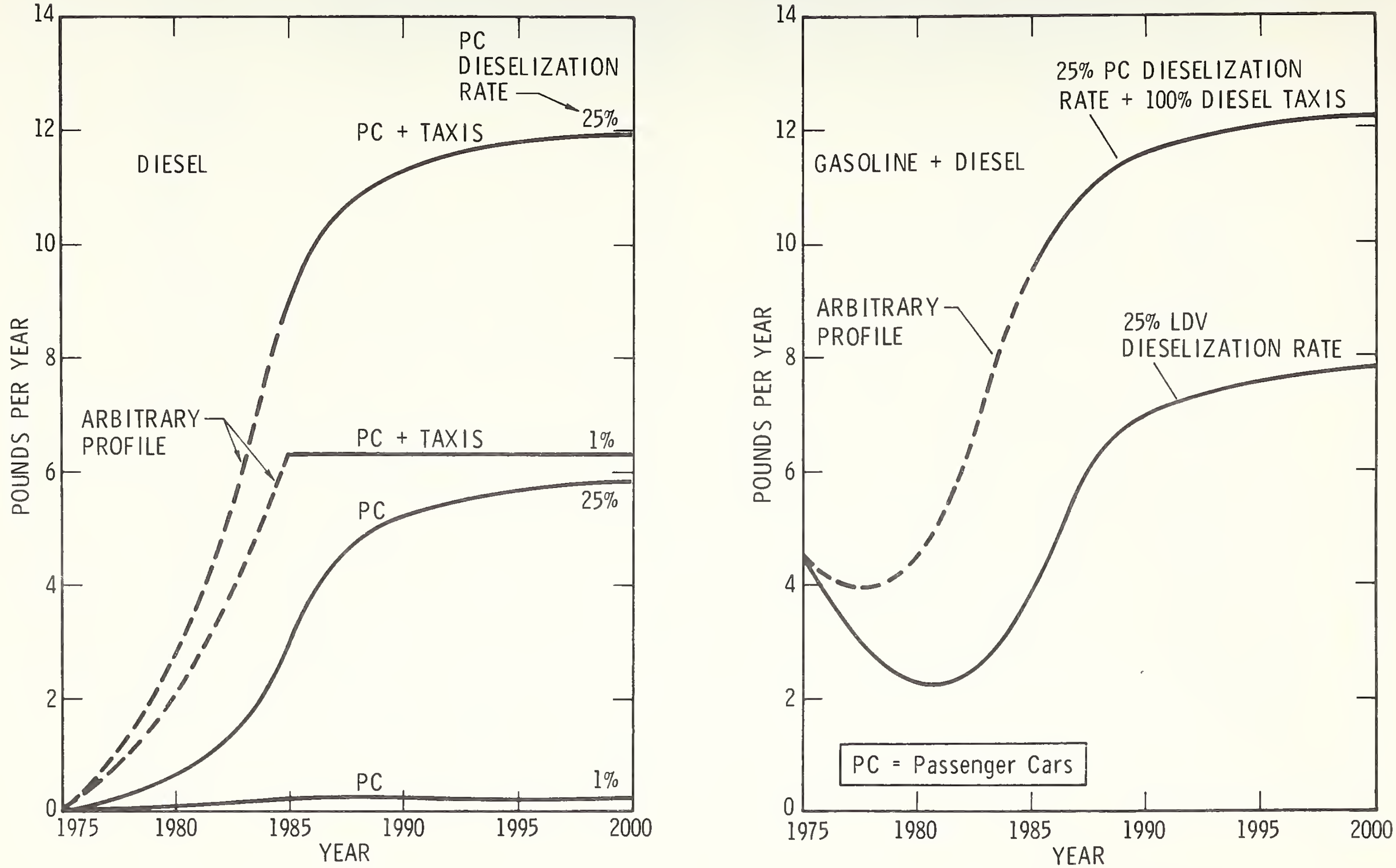

Figure 4-14. Manhattan 100-Percent Taxi Dieselization -- Diesel LDV and Total LDV BaP Effects (High Estimate)

compared to a level of about 8 pounds per year for the 25-percent LDV dieselization scenario.

4.1.2 St. Louis

Results of the pollutant dump calculation for St. Louis are shown graphically in Figures 4-15 through 4-26 (numerical values are listed in Appendix D).

Because the geographical area encompassed by the St. Louis region is substantially larger than Manhattan, with a correspondingly higher VMT for all vehicle classes, all the plots for St. Louis will be found to show significantly higher levels of dump than the corresponding plots for Manhattan. In addition, unlike Manhattan, the St. Louis authorities project a moderate VMT growth for the region; about 25 percent by the year 2000, for all vehicle classes. In general, the VMT growth effect influences the plot characteristics so as to cause a longer curve climb-out to peak values. Indeed, in a number of cases, the curves continue to rise throughout the period of interest and eventually peak beyond the year 2005.

The effects described above may be observed, for example, in the case of the LDVD particulate characteristic, shown in Figure 4-15 (top), which continues to rise beyond the 1985 period, even though new vehicles entering the fleet from this time forward are controlled well below the fleet average emission rate (see Table 2-9). For this pollutant, the dump at the 25-percent dieselization rate reaches 930 tons per year in the year 2000.

Another aspect of the VMT growth effect may be observed in the HDVD NO_x dump characteristic shown in Figure 4-23 (right). The dump profile exhibits the same double-peak characteristic shown for Manhattan, but the peaks are shifted toward the later projection years.

Aside from the effects discussed above, all the mobile source plots for St. Louis behave similarly to those for Manhattan, and the reader is referred to the discussion under Section 4.1.1 for explanations as to the cause of the curve trends.

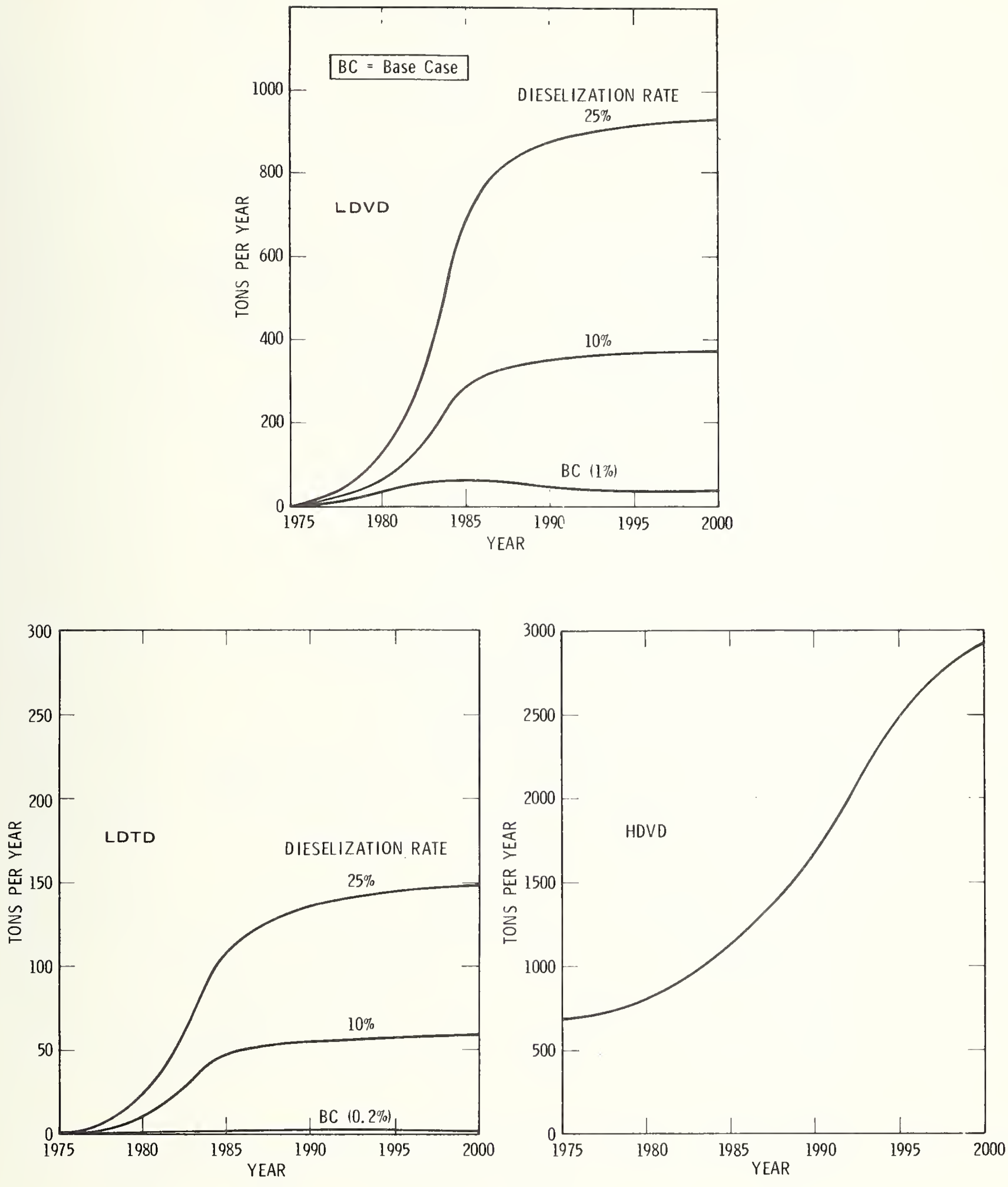

Figure 4-15. St. Louis Particulate Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

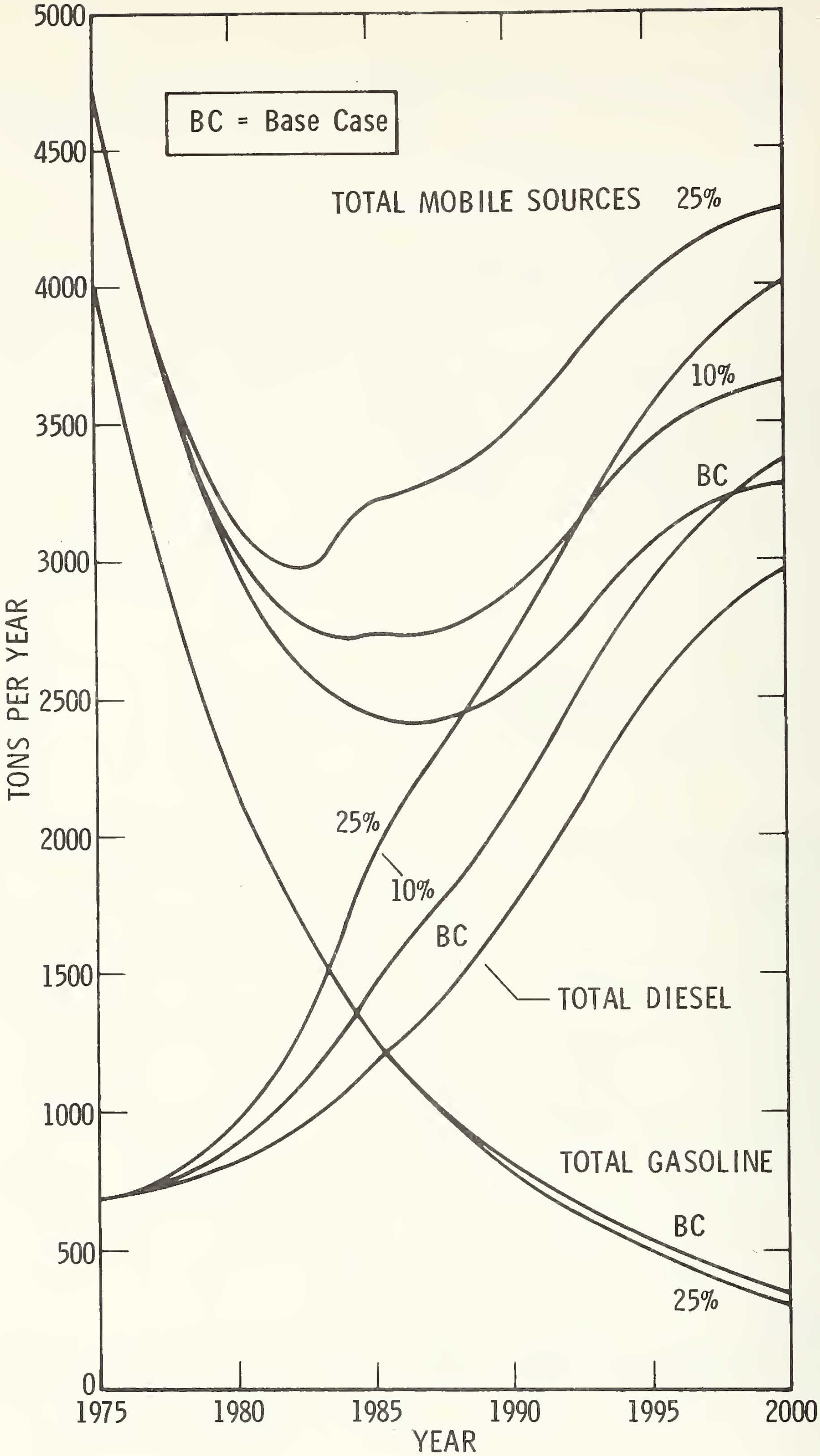

Figure 4-16. St. Louis Particulate Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

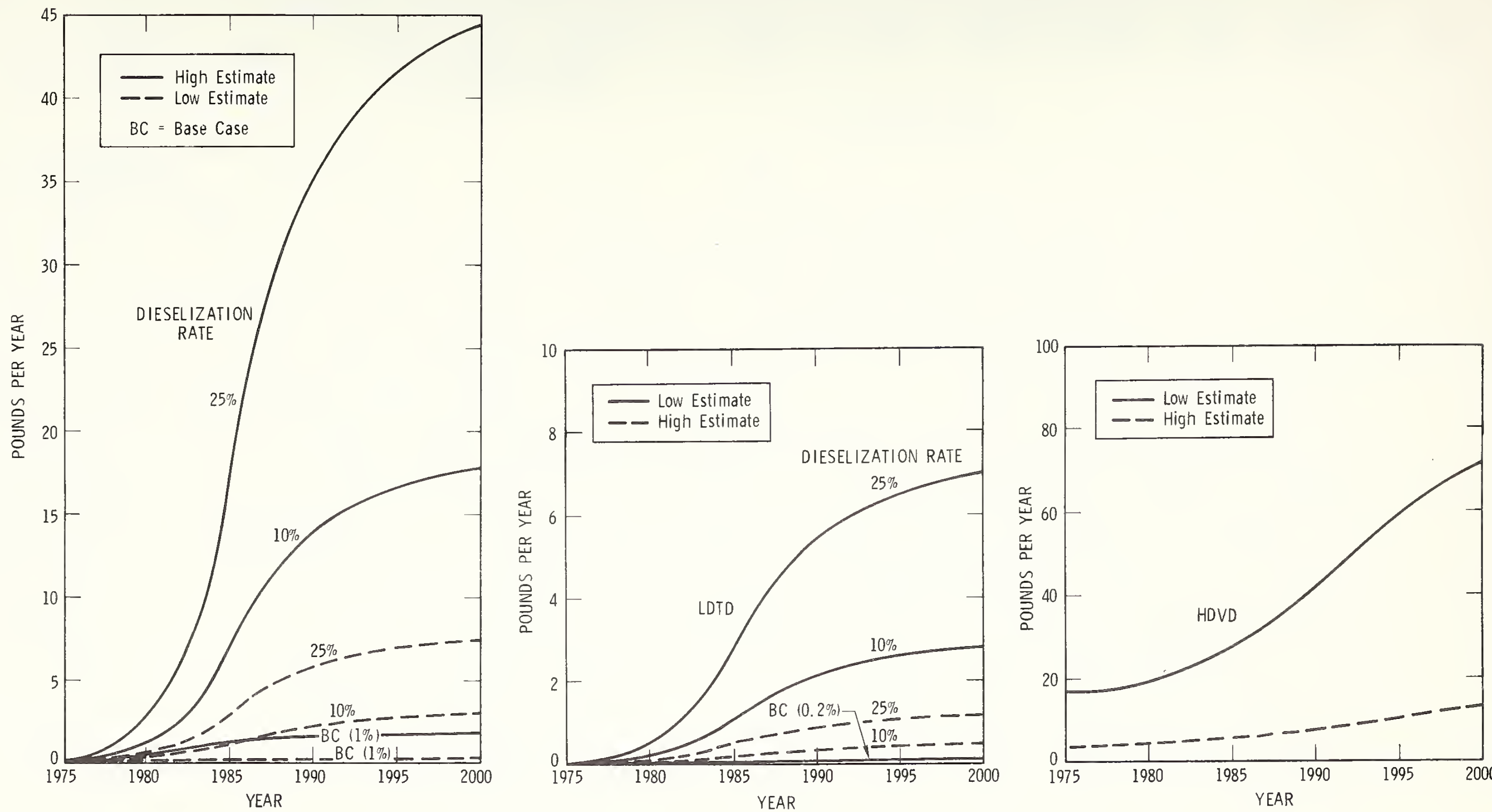

Figure 4-17. St. Louis BaP Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

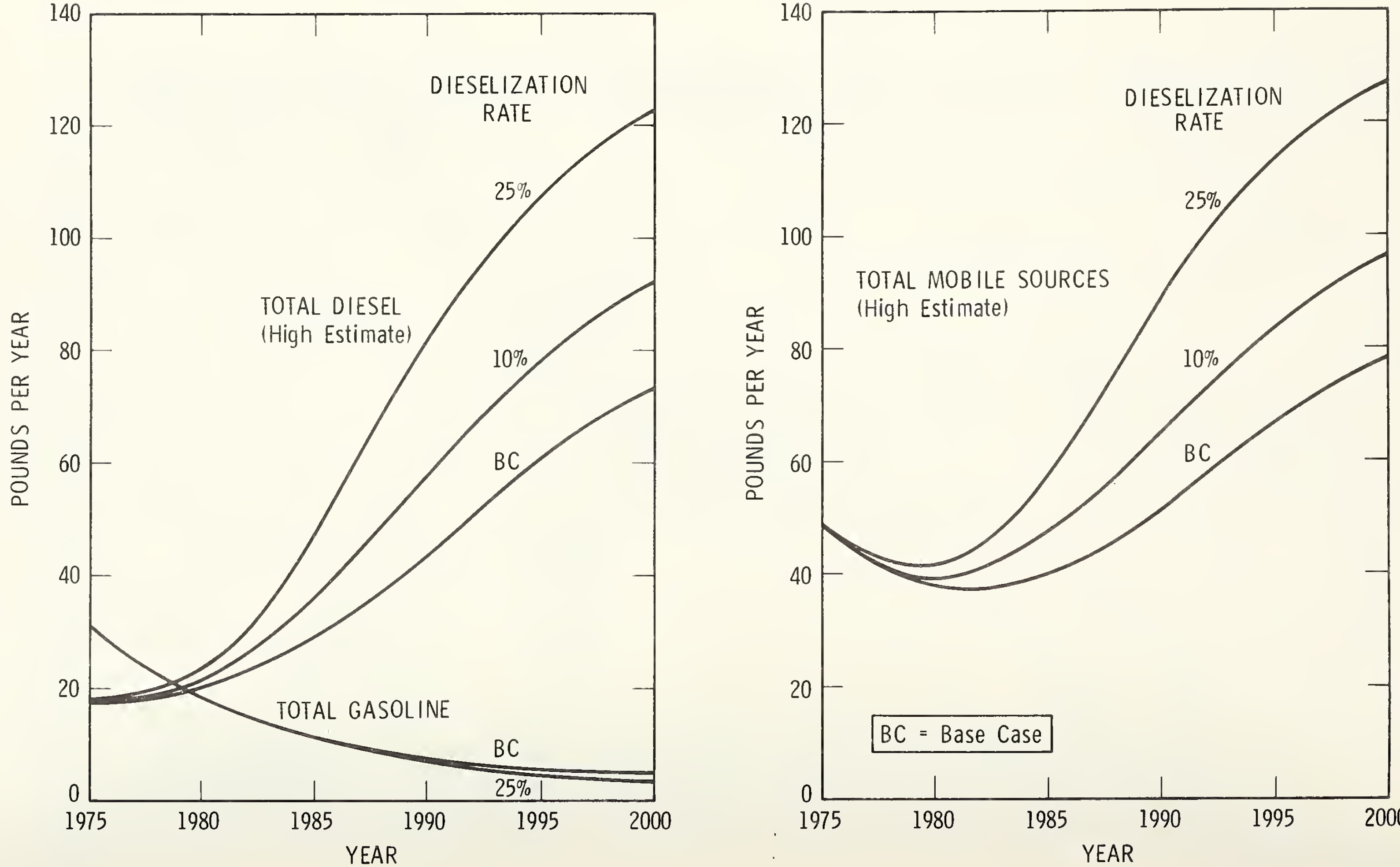

Figure 4-18. St. Louis BaP Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions (High Estimate)

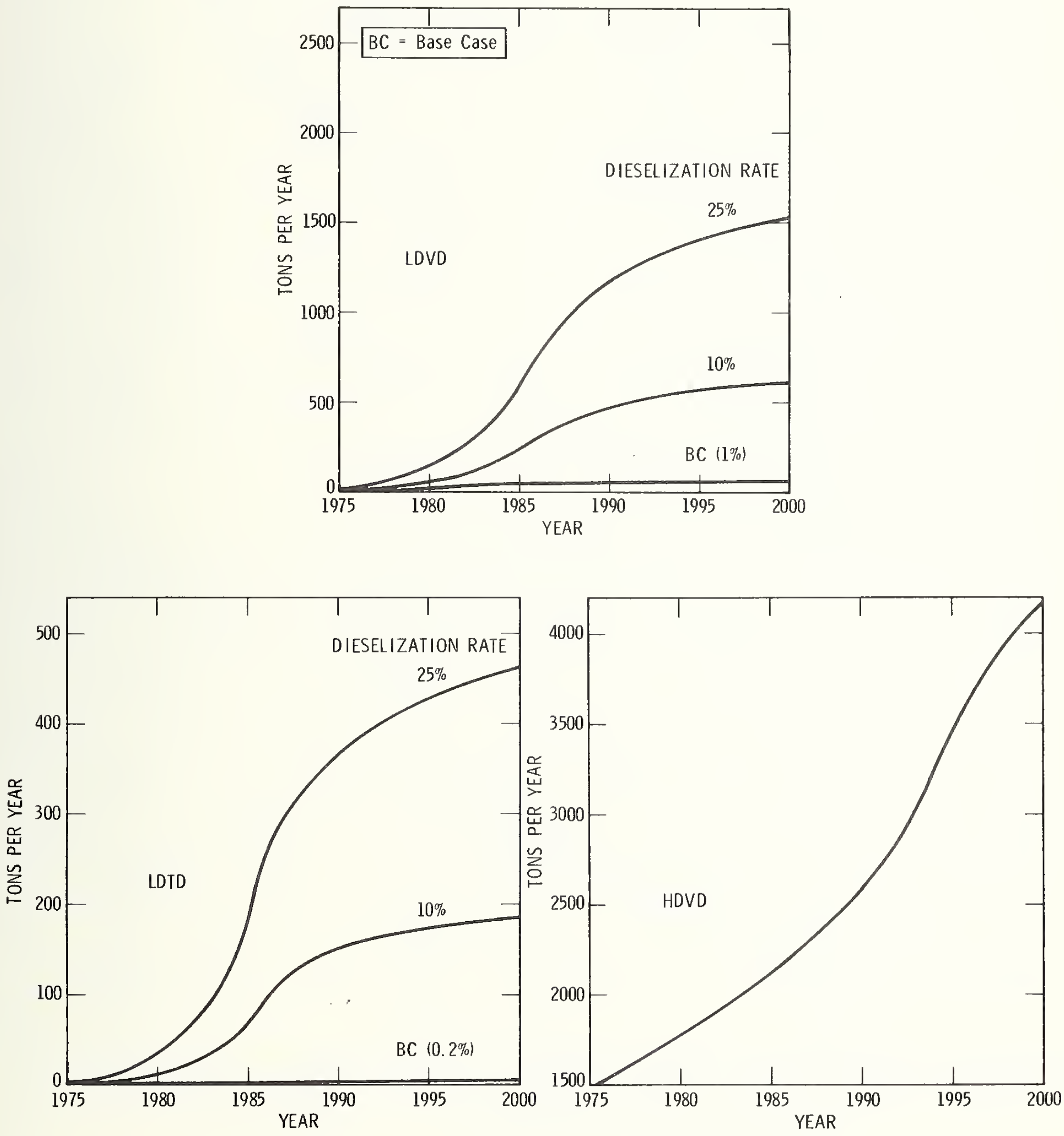

Figure 4-19. St. Louis HC Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

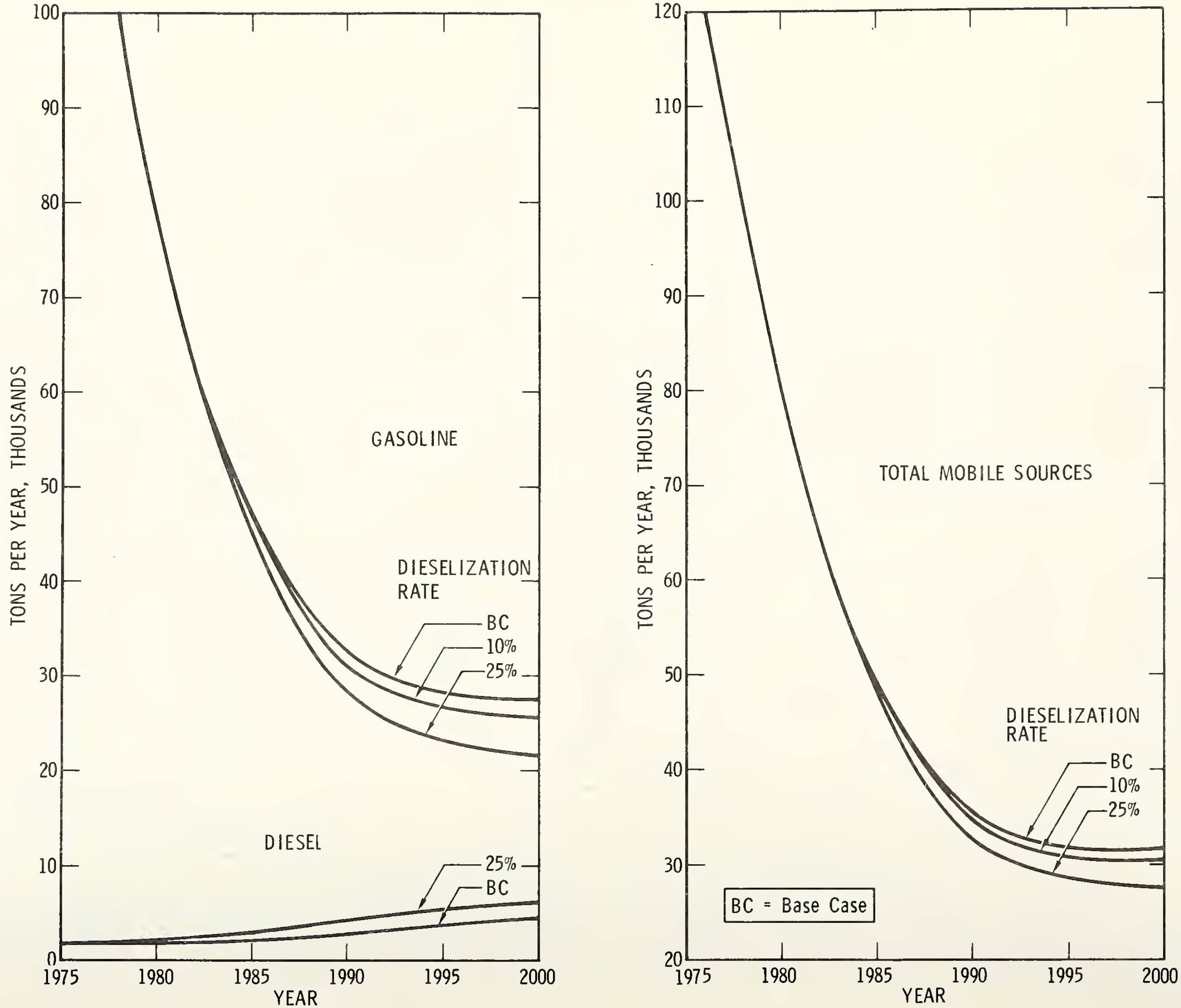

Figure 4-20. St. Louis HC Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust and Evaporative/Crankcase Emission Contributions

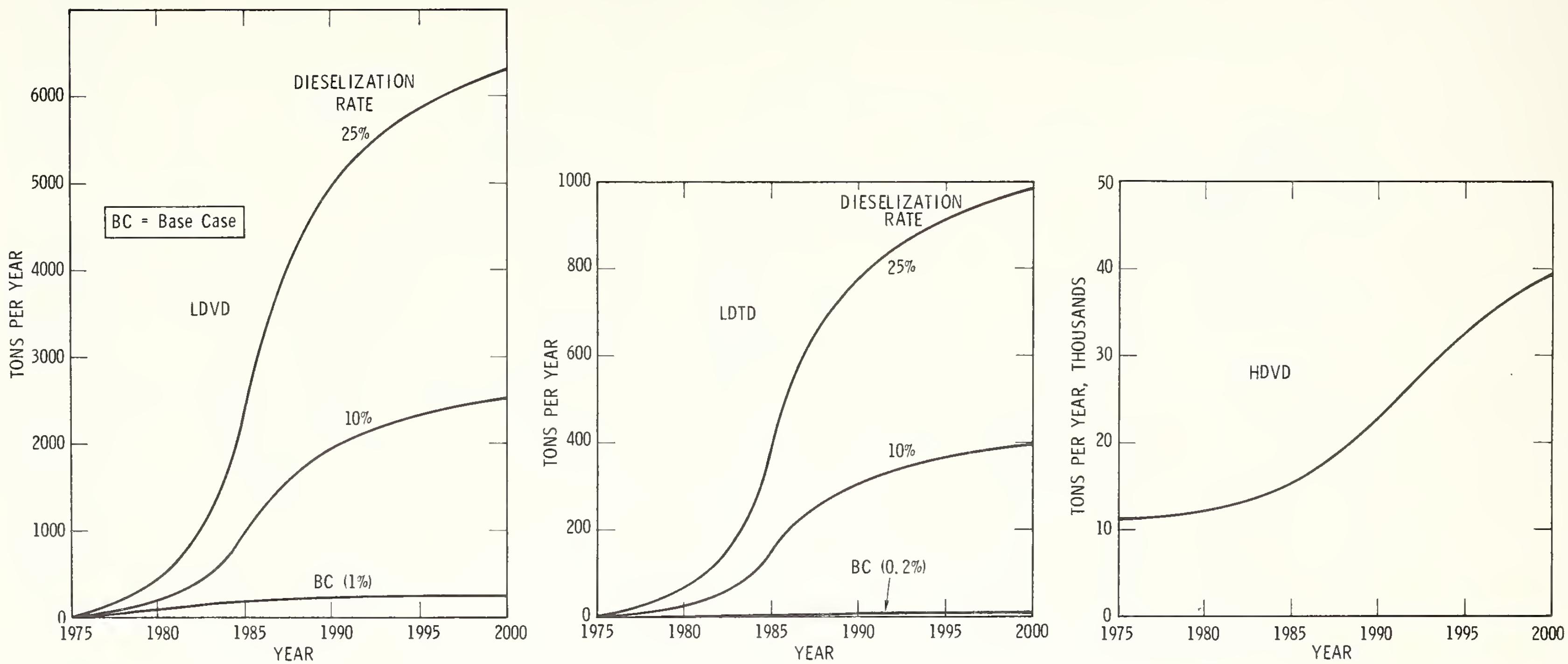

Figure 4-21. St. Louis CO Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

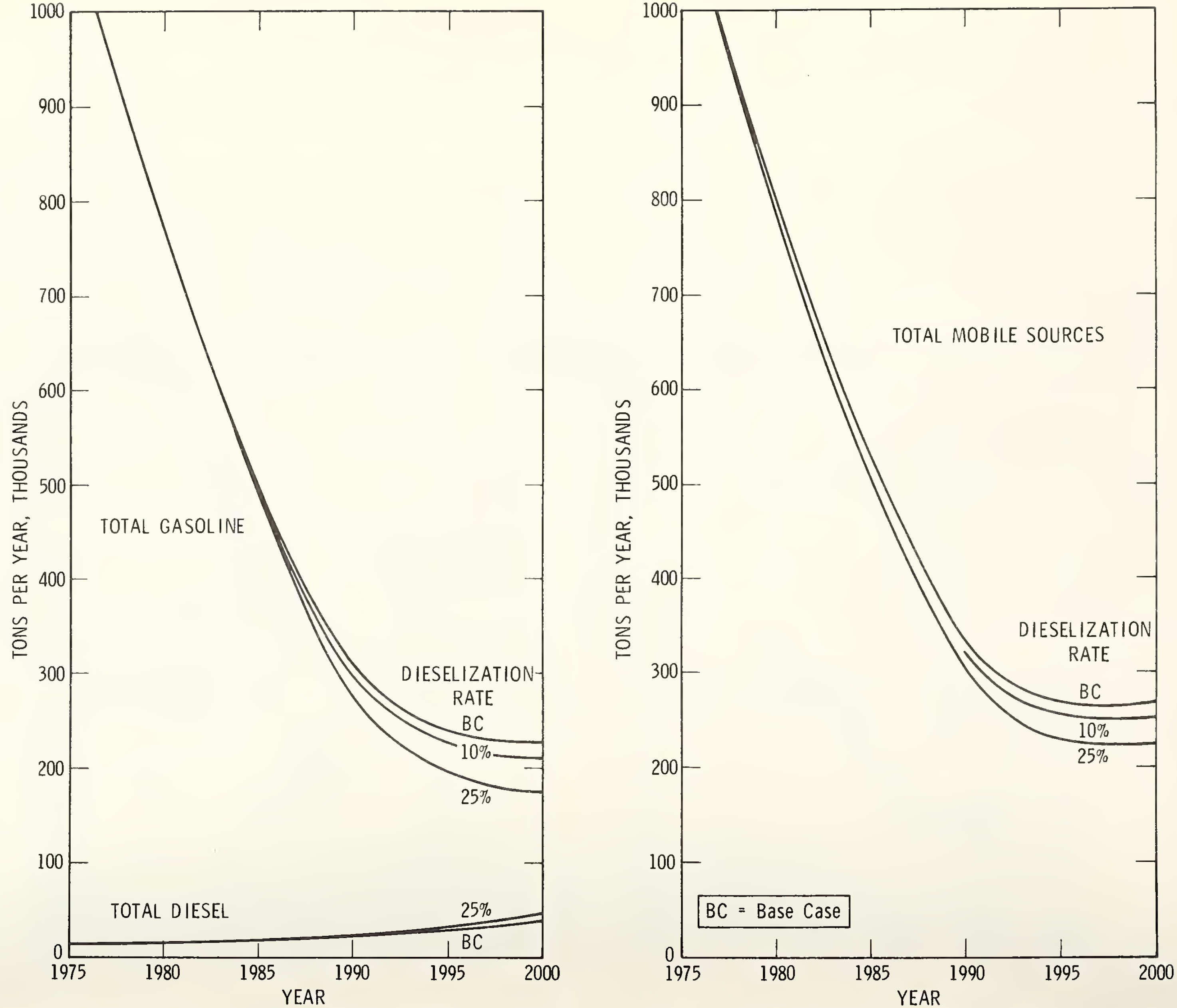

Figure 4-22. St. Louis CO Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

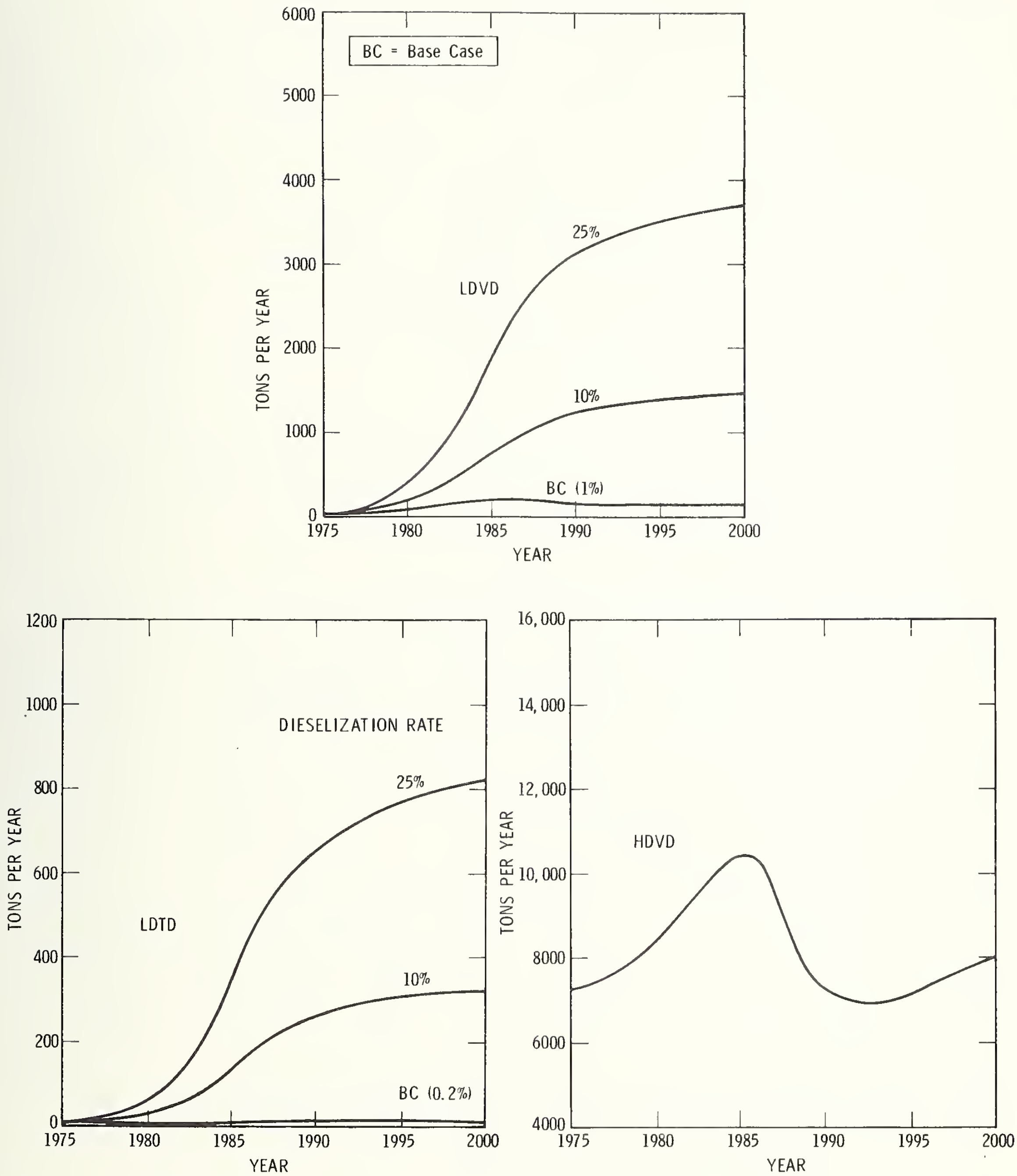

Figure 4-23. St. Louis NO_x Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

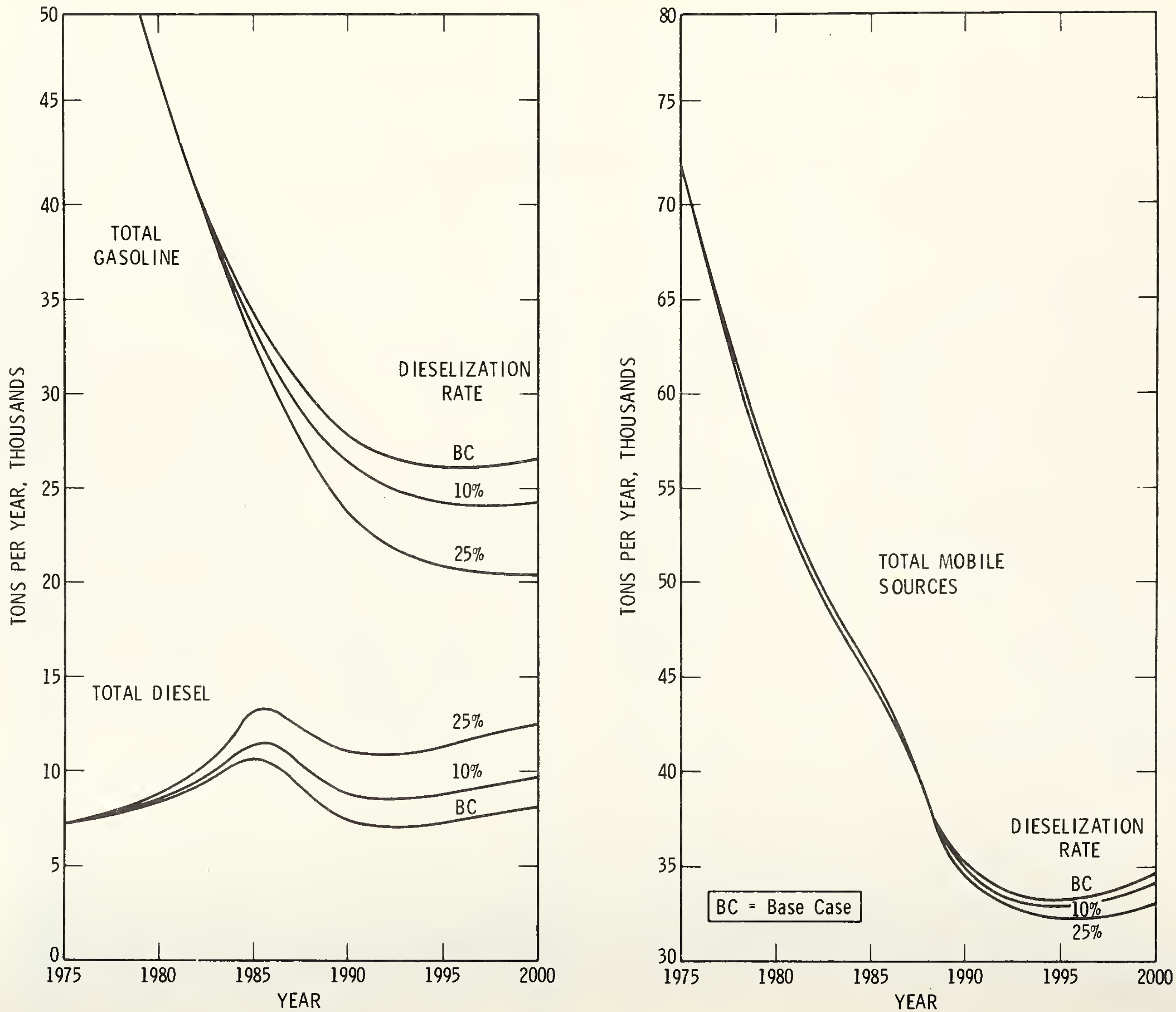

Figure 4-24. St. Louis NO_x Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

Stationary source contributions to the St. Louis area dump are shown in Figure 4-25. Consistent with the moderate growth in population and employment projected for this region, all the pollutants with the exception of fugitive dust show an increasing trend. The negative slope indicated for fugitive dust is the result of a reduction in the number of miles of unpaved streets (see Section 2.2.3.2).

The sums of mobile and stationary source contributions for St. Louis are shown in Figure 4-26. At the scale plotted, the reduction in HC and NO_x (see Figures 4-20 and 4-24) and the increase in particulates (see Figure 4-16) due to LDV dieselization cannot be discerned.

4.1.3 Phoenix

Results of the pollutant dump calculations for Phoenix are shown graphically in Figures 4-27 through 4-38. Numerical values for the Phoenix dump are provided in Appendix D.

The principal distinction of the dump characteristics for Phoenix is that the curves continue to rise or, having reached a minimum, show a tendency to rise again within the time frame of interest. This is caused by the substantial growth in projected VMT for the Phoenix area, which is indicated in Table 2-7 to range from 103 percent in the case of HDV's to about 117 percent for LDV's and LDT's.

The VMT influence may be seen, for example, in the plot for LDVD particulates in Figure 4-27 (left), where the curves (for 10-percent and 25-percent dieselization) display a steep positive slope after 1985 even though the LDV dieselization rate in this period is constant. The curves approach the slope of VMT in 2005, when all vehicles in the LDVD group theoretically emit at the same particulate emission rate (0.25 g/mi). Thereafter, the slopes follow the trend of VMT in a one-to-one relationship. The dump level indicated for the 25-percent dieselization rate is about 720 tons per year in the year 2000.

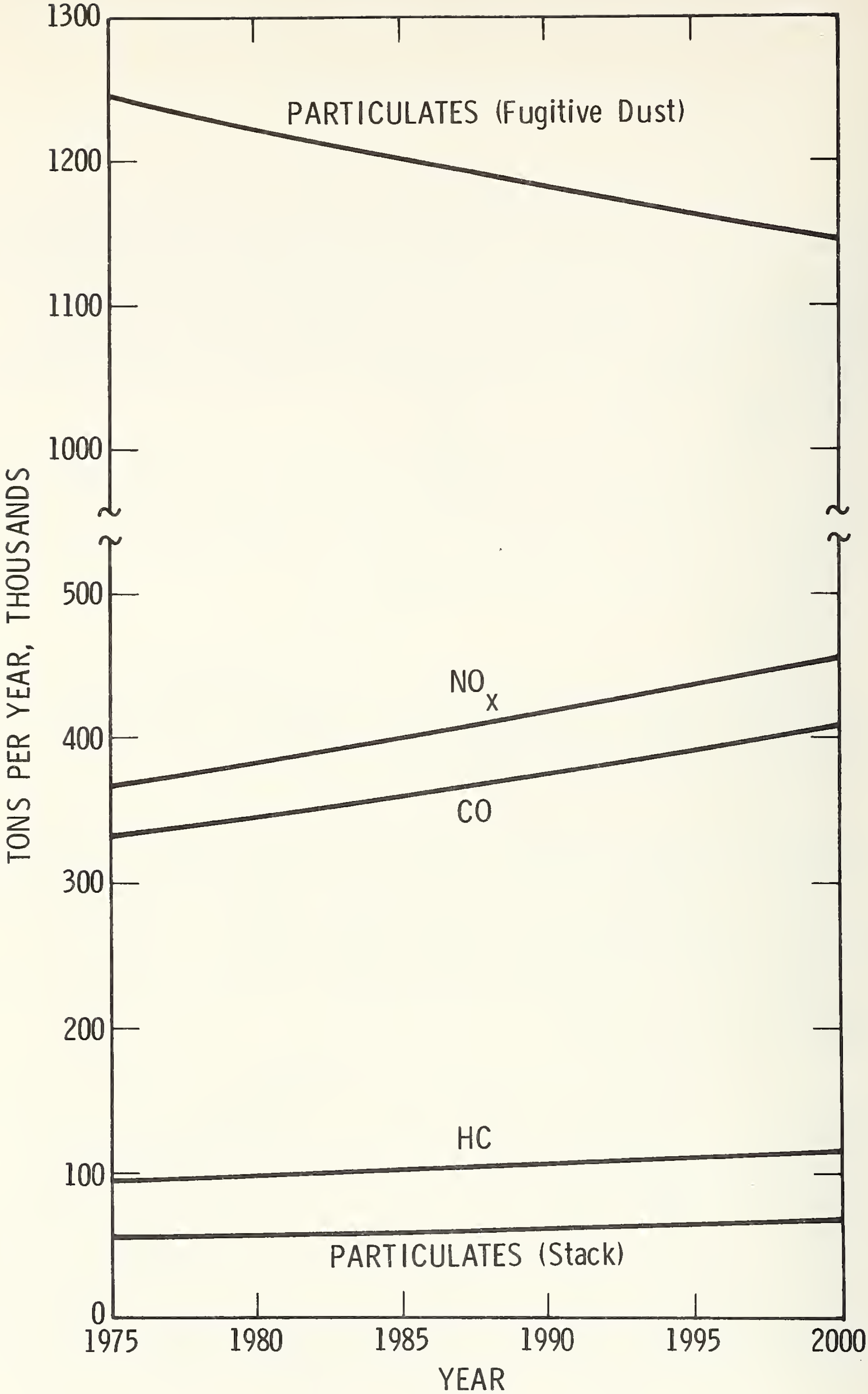

Figure 4-25. St. Louis Pollutant Dump -- Stationary Source Contributions

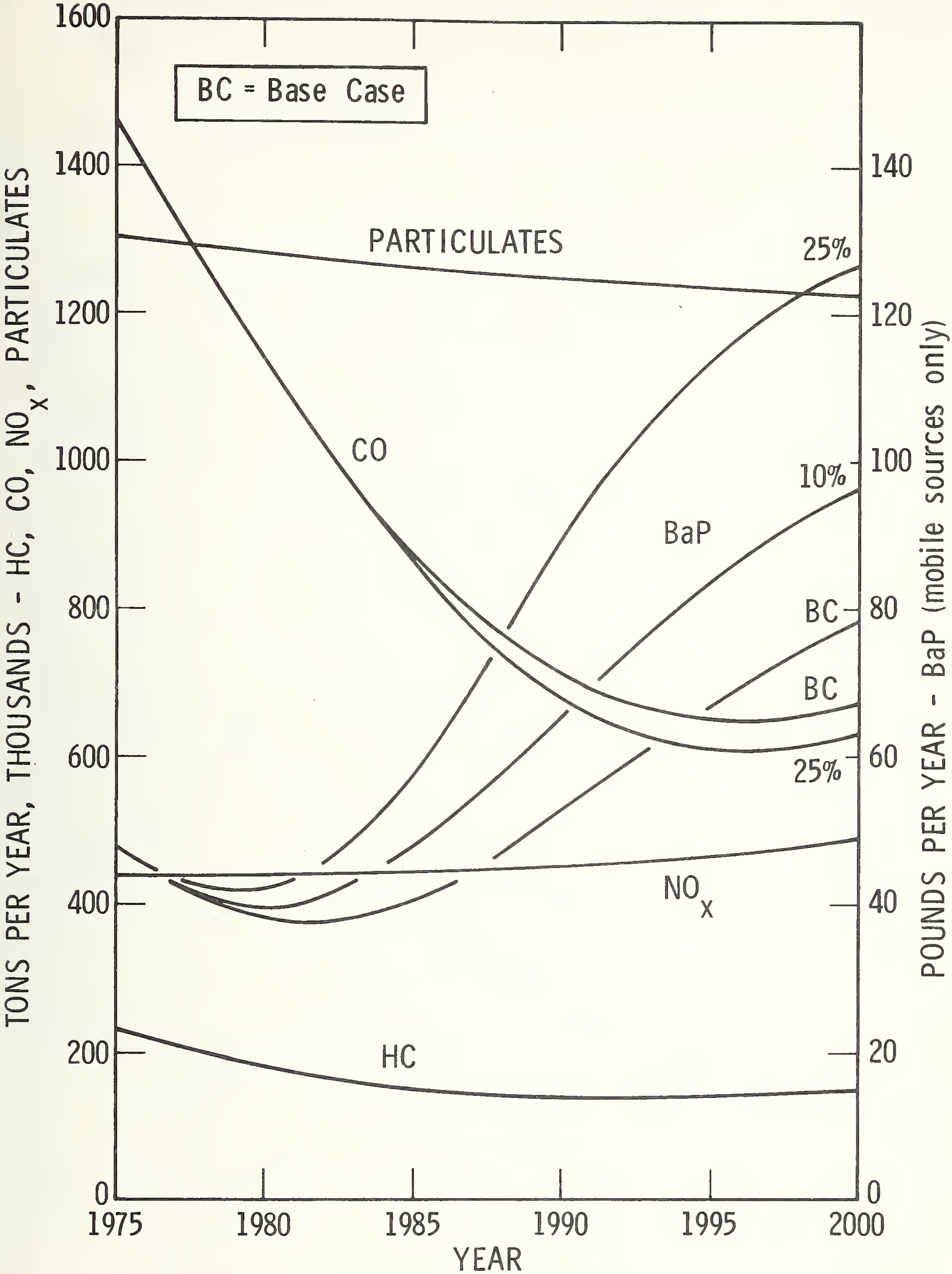

Figure 4-26. St. Louis Pollutant Dump -- Mobile Plus Stationary Source Contributions

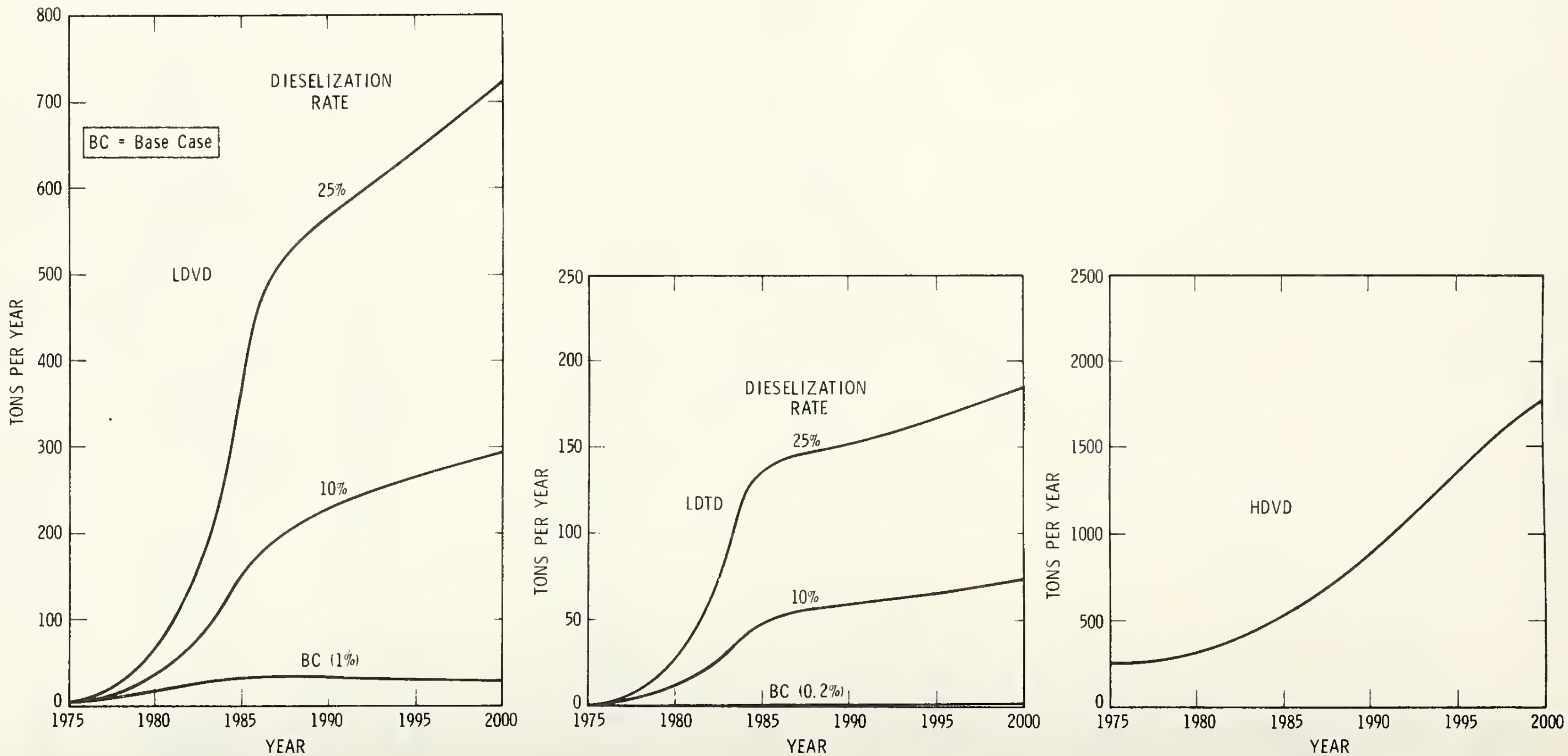

Figure 4-27. Phoenix Particulate Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

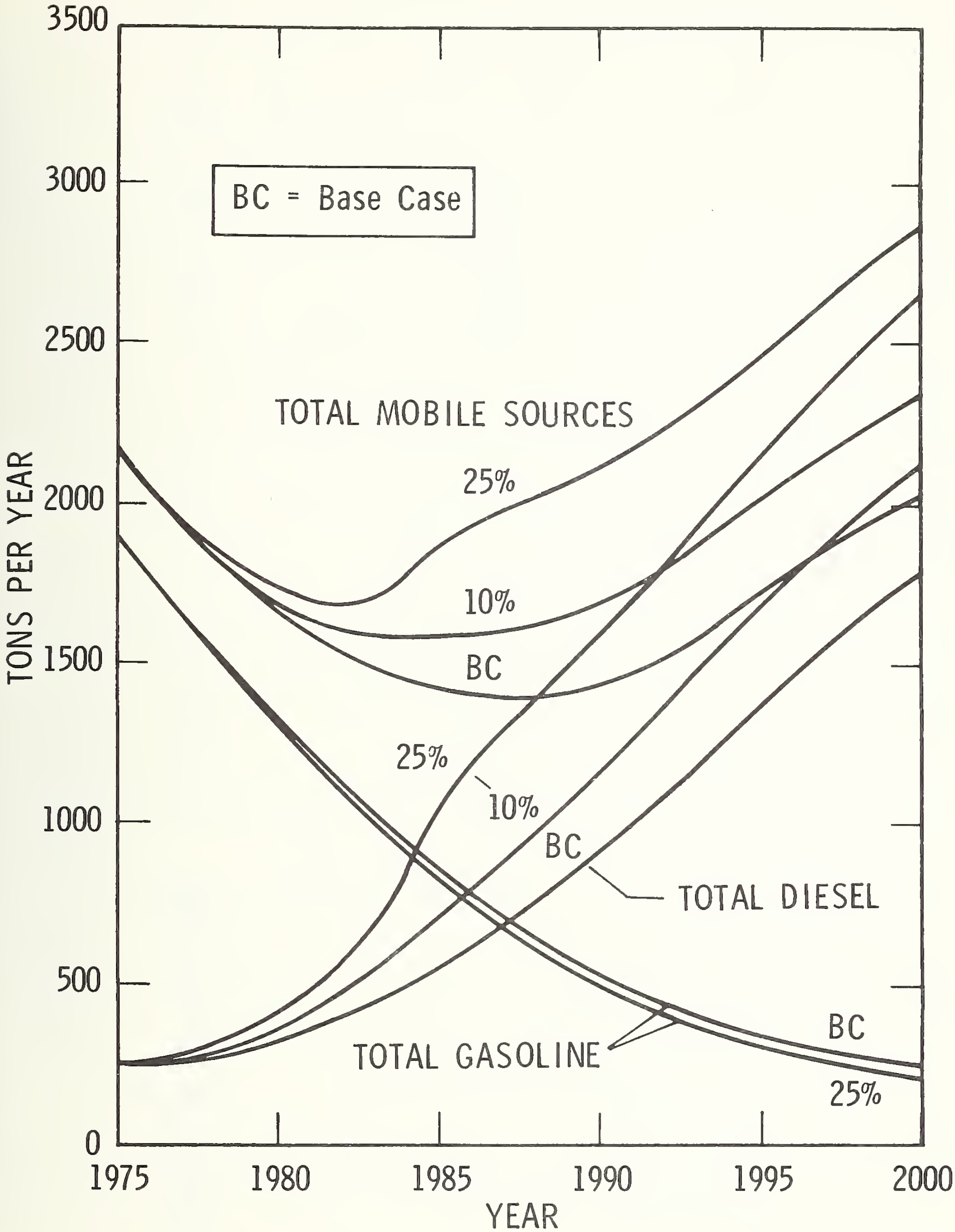

Figure 4-28. Phoenix Particulate Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

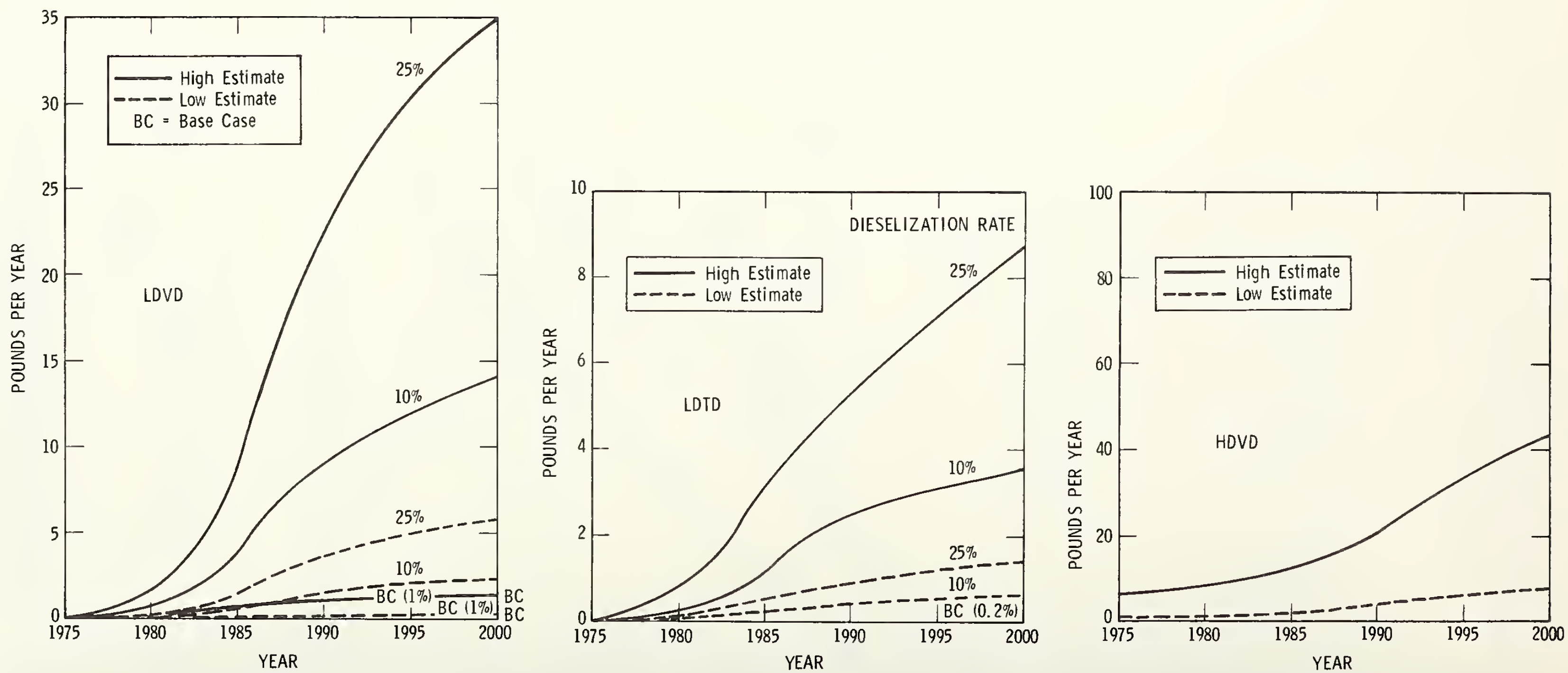

Figure 4-29. Phoenix BaP Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

Figure 4-29. Phoenix BaP Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

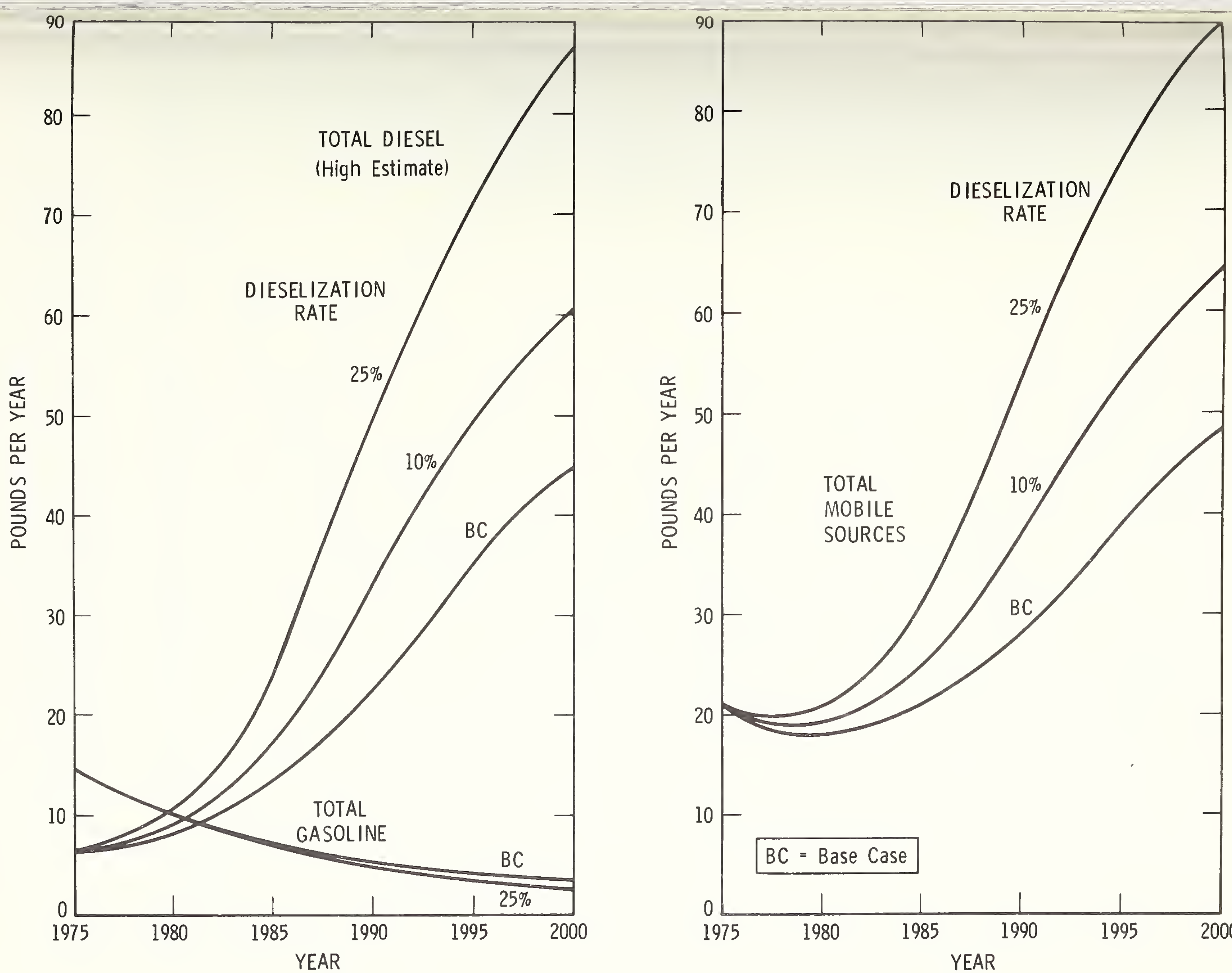

Figure 4-30. Phoenix BaP Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions (High Estimate)

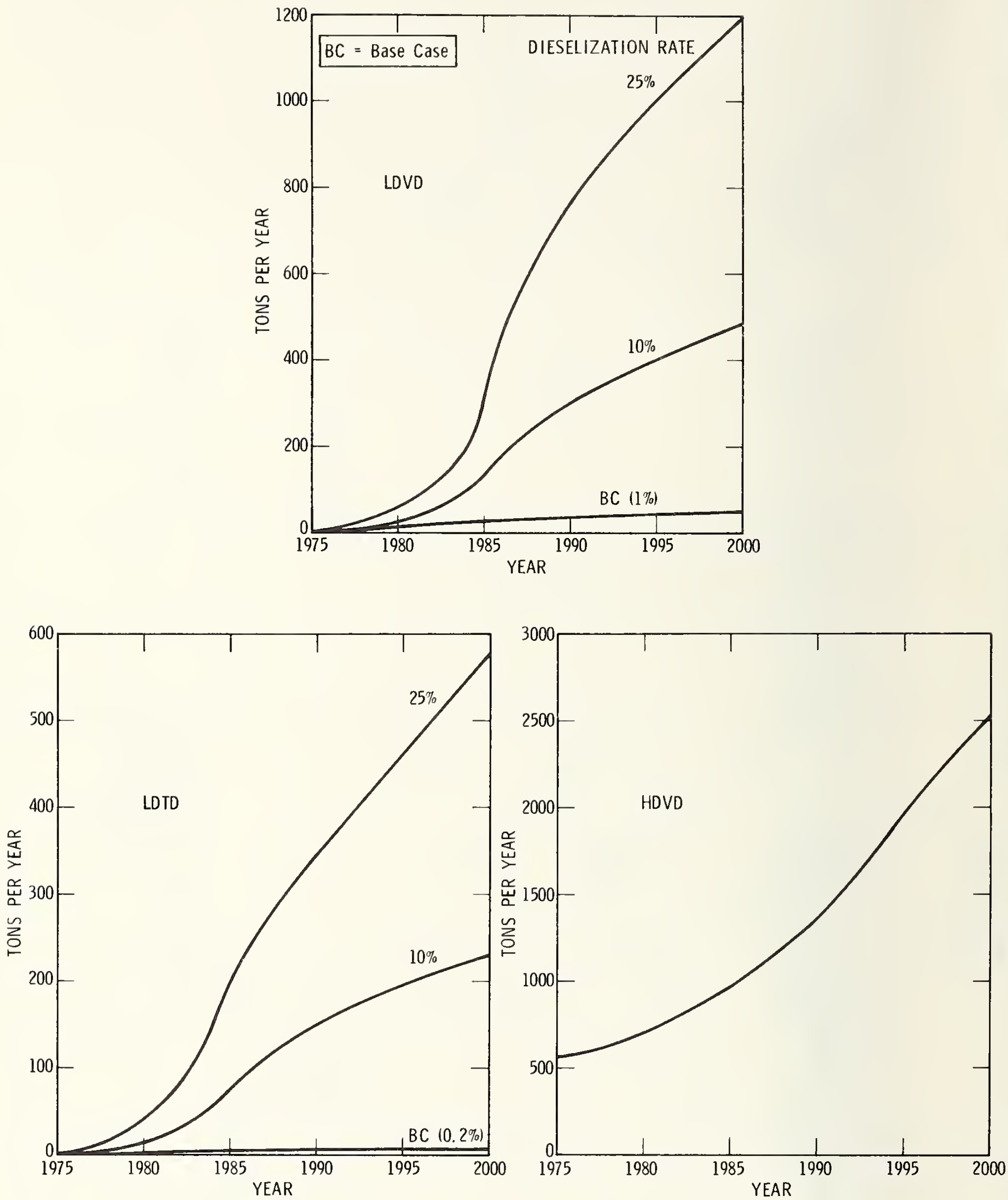

Figure 4-31. Phoenix HC Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

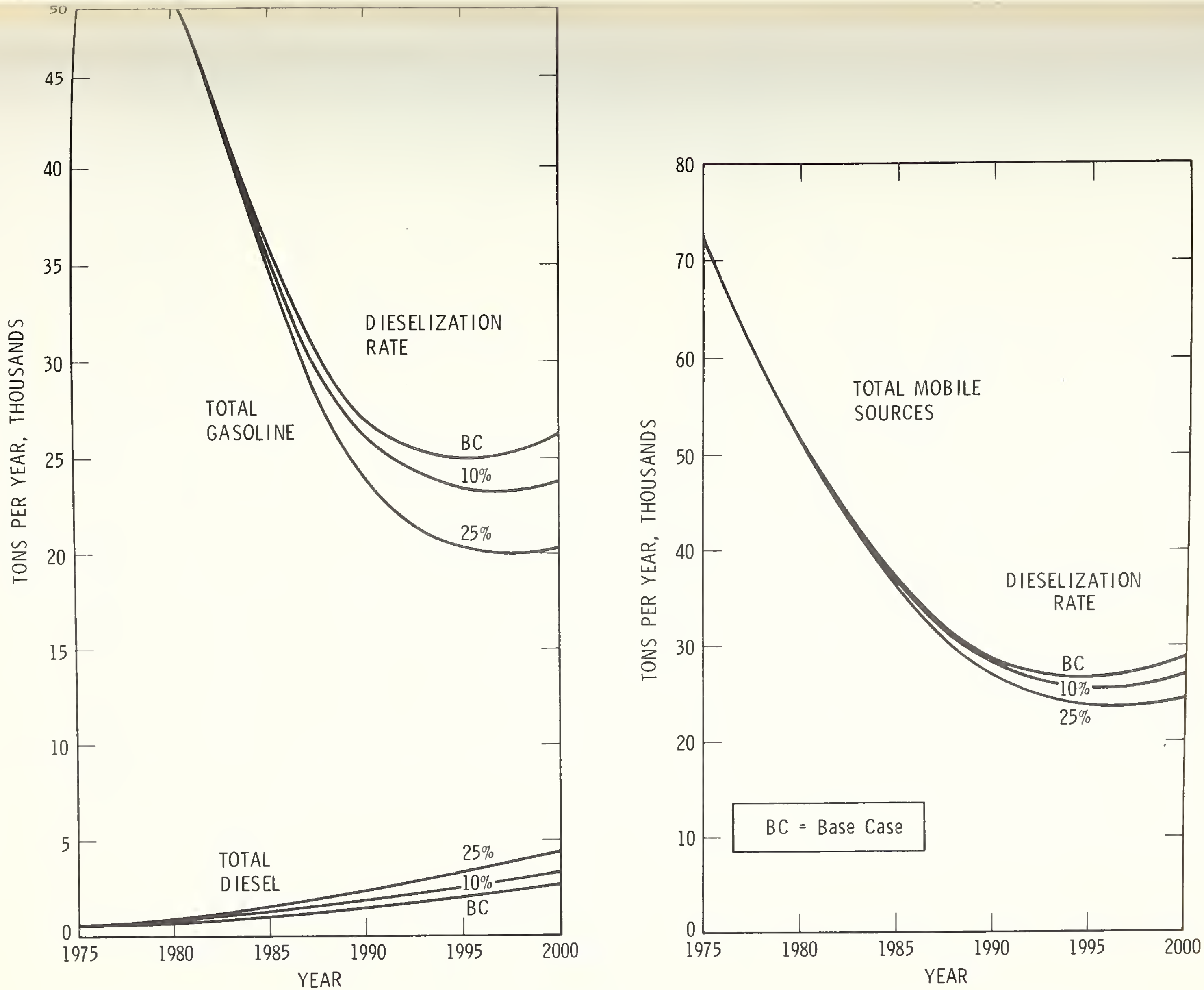

Figure 4-32. Phoenix HC Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust and Evaporative/Crankcase Emission Contributions

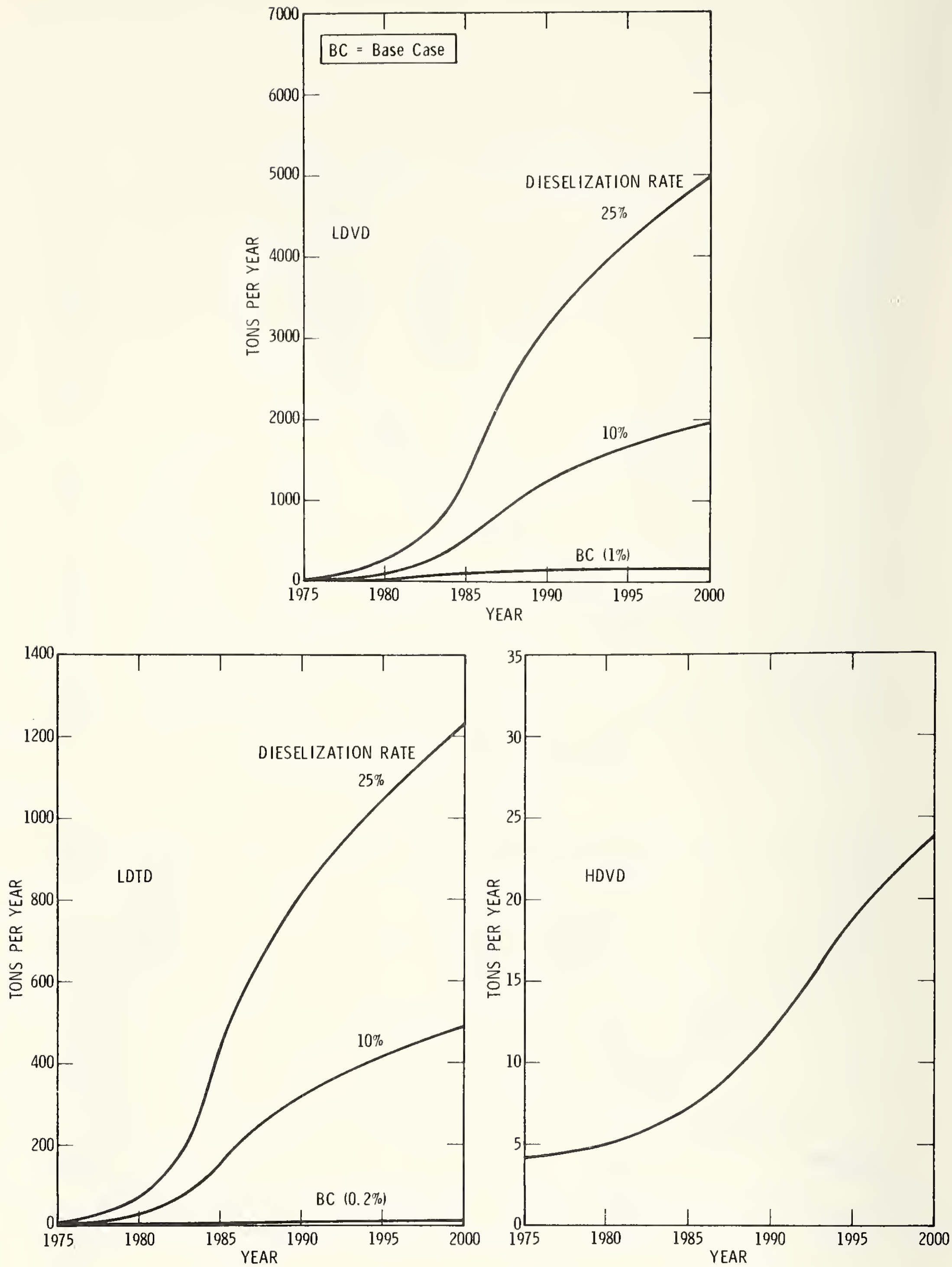

Figure 4-33. Phoenix CO Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

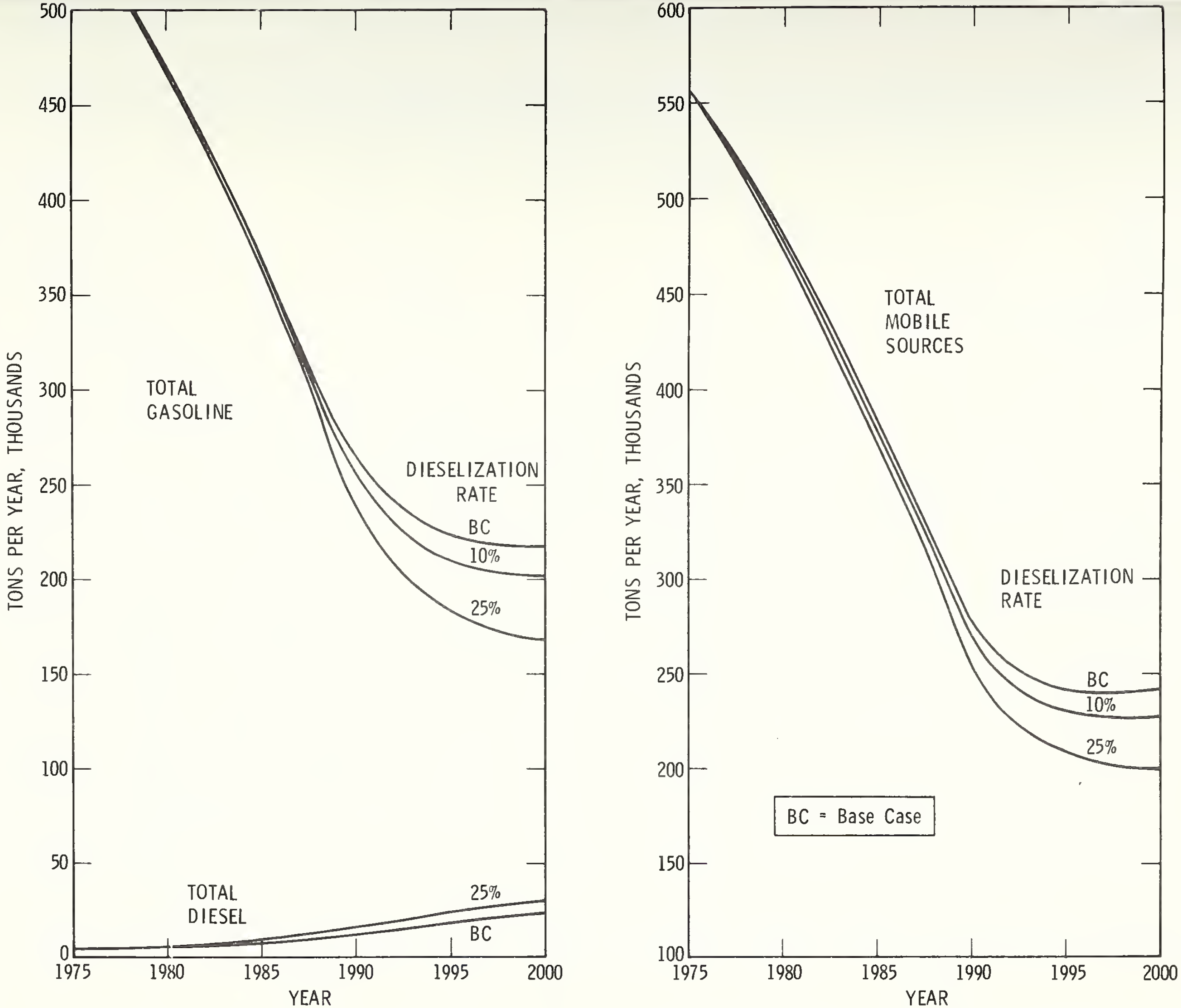

Figure 4-34. Phoenix CO Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

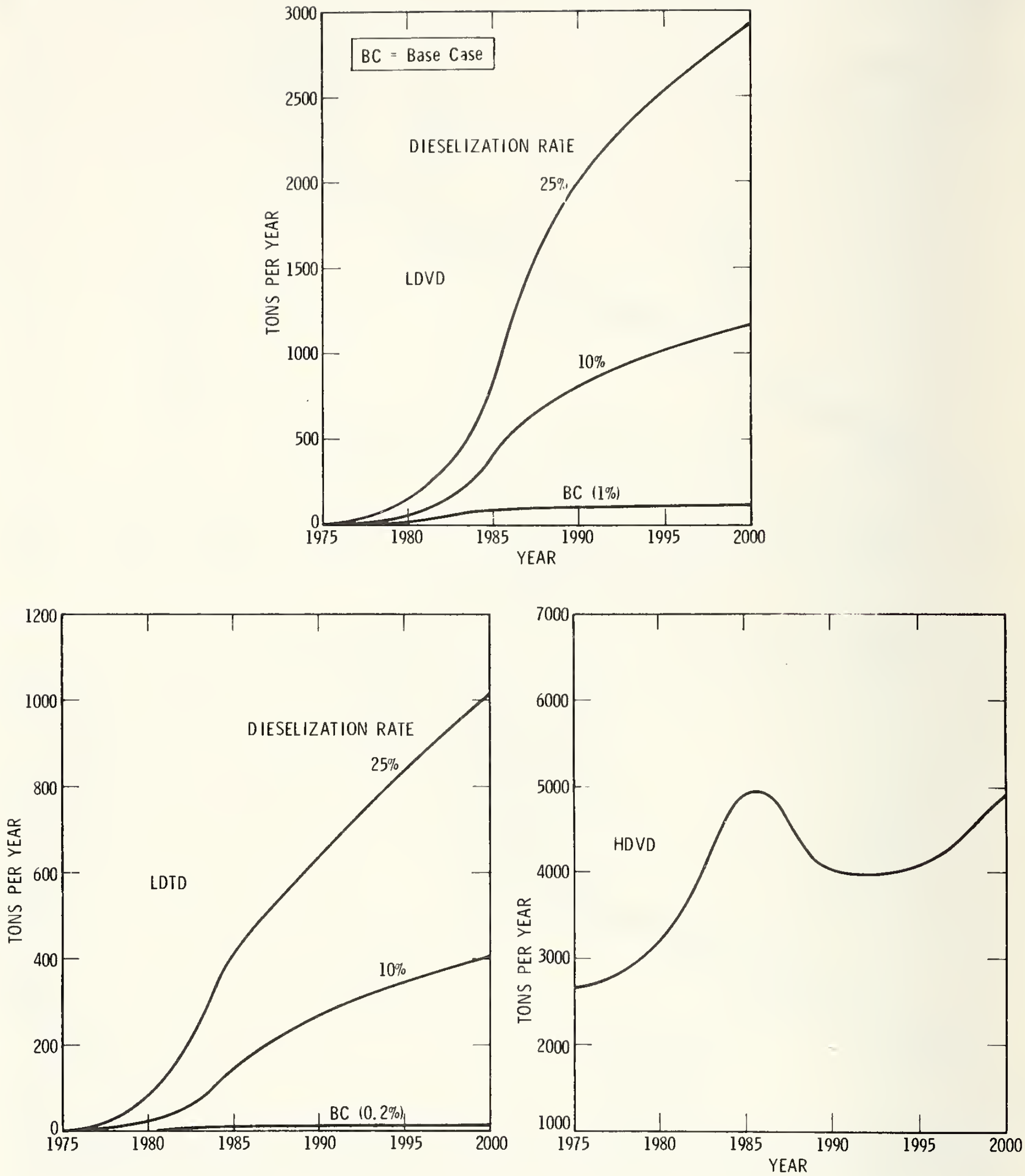

Figure 4-35. Phoenix NO_x Dump -- Diesel LDV, LDT, and HDV Exhaust Emission Contributions

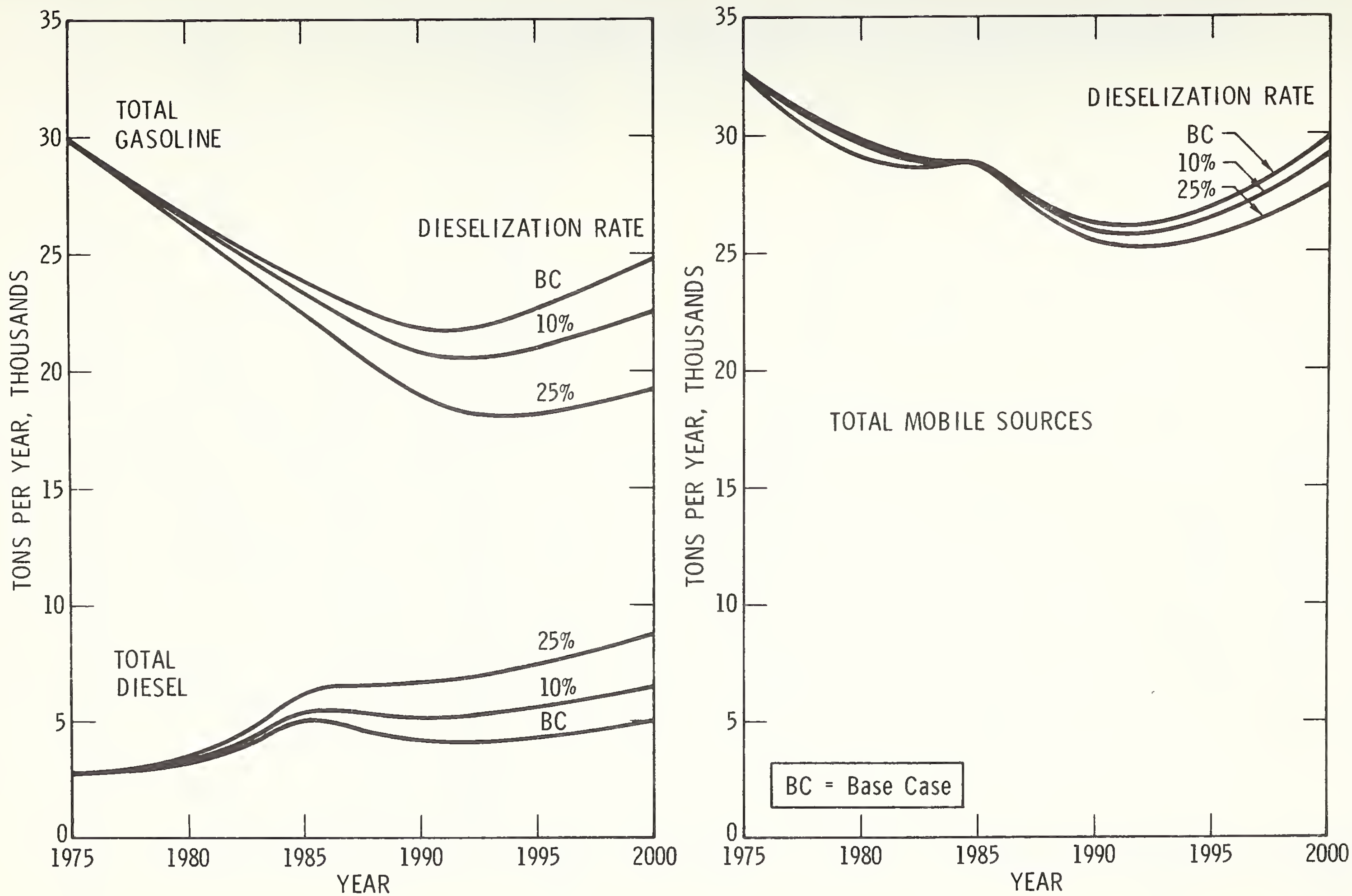

Figure 4-36. Phoenix NO_x Dump -- Total Diesel, Total Gasoline, and Total Mobile Source Exhaust Emission Contributions

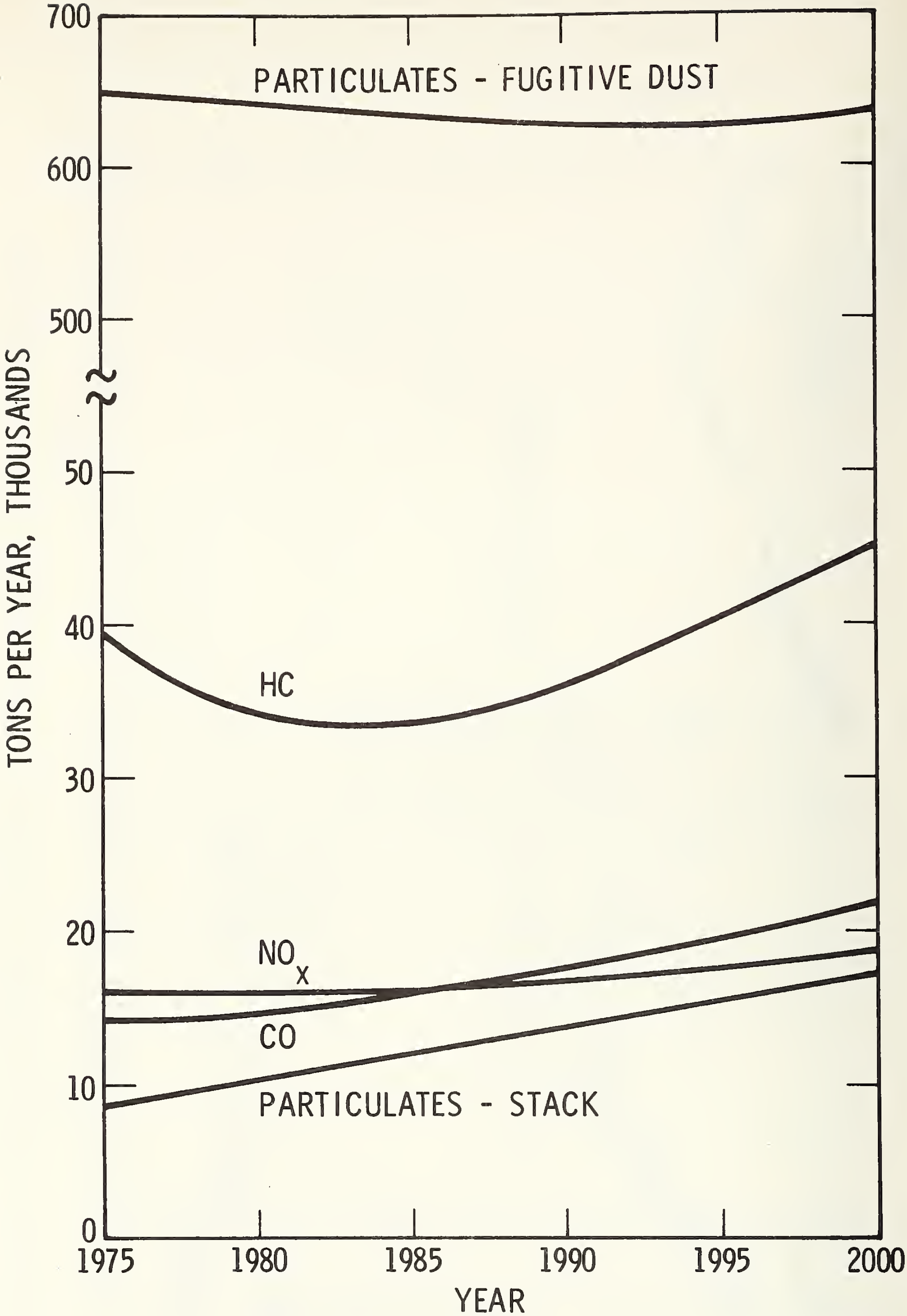

Figure 4-37. Phoenix Pollutant Dump -- Stationary Source Contributions

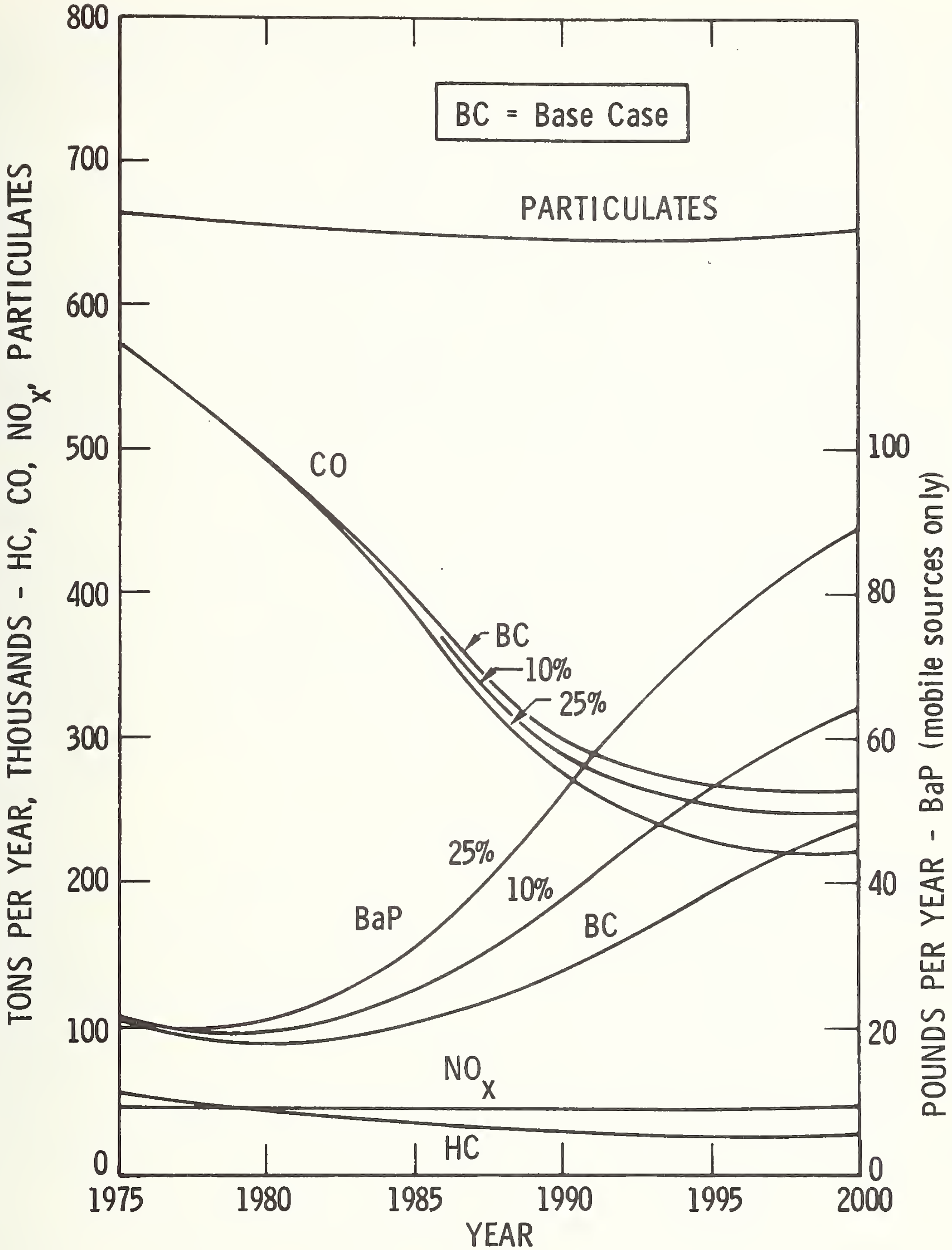

Figure 4-38. Phoenix Pollutant Dump -- Mobile Plus Stationary Source Contributions

The trends discussed above may also be seen in the curves for LDTD's in Figure 4-27 (center), while the HDVD plot (right) reflects the VMT effect in the strong positive slope shown to continue through the year 2000.

The VMT effect is also contained in the total gasoline particulate curve given in Figure 4-28. This is indicated by the relatively shallow slope of the curves as compared to the corresponding characteristics for Manhattan and St. Louis. It is also visible in the curves shown for the total gasoline HC dump (Figure 4-32), which reach a minimum and rise again in the 1995 - 2000 time period. The gasoline CO dump in Figure 4-34 (left), and total mobile source CO dump in Figure 4-34 (right), exhibit the VMT effect by a reversal of curvature in the descending portion of the curves.

The sums of stationary and mobile source emissions are given in Figure 4-38. The downward trend of HC and CO is due solely to mobile source control measures in the gasoline component of the vehicle fleet. The effects of LDV dieselization are masked by the scale of the plot for all pollutants except BaP (shown for vehicle sources only) and CO, which is dominated by the mobile source contribution.

4.2 LOCAL SITE RESULTS

4.2.1 Urban Freeway

4.2.1.1 Particulates

Using the 50th-percentile ψ characteristic developed in Section 3.2.2, exhaust particulate concentrations were calculated as a function of distance from the roadway edge for a range of traffic counts and for various projection years and LDV dieselization rates. The special case of 100-percent dieselization of the Manhattan taxicab fleet was also treated, using the adverse assumption for vehicle age distribution discussed in Section 4.1.1.2.

As described in Section 3.2.3, the concentrations are computed as the product of the 50th-percentile value of ψ at the appropriate distance from the roadway edge (from Figure 3-2), the particulate emission factor applicable to the scenario case under consideration (EF), and the traffic count (TC). The emission factors used in the computations represent fleet composite statistics for Manhattan and are developed from the results of the areawide pollutant dump analysis given in Section 4.1.1 (EF = Σ Dump/Σ VMT). Both diesel-only and total mobile source particulates are considered.

The traffic count called for in the concentration relationship represents total traffic flow (veh/hr) considering both directions of traffic movement. Review of traffic count information given in the freeway data bases (Section 3.2.2) and in CalTrans and EPA surveys of the Los Angeles area (Refs. 4-3, 4-4) established that a traffic rate of 1500 vehicles per hour per lane was a reasonable estimate of maximum freeway traffic density (typically seen in the morning and evening rush periods). This study considers the case for an eight-lane freeway, which at maximum traffic density exhibits a traffic count of 12,000 vehicles per hour.

As a frame of reference for assessing the significance of future LDV dieselization effects, Table 4-2 presents the results of concentration calculations at selected traffic conditions for the baseline year of 1975. Values are shown for diesel-only and total mobile source particulate concentrations for several roadway-site positions of interest and for a range of traffic counts from 3000 to 12,000 veh/hr. These data are plotted in Figure 4-39.

Results projected through the year 2000 at these same roadway positions, for the maximum traffic count case of 12,000 veh/hr, are listed in Table 4-3. Included here are results for the Manhattan taxi scenario in which 100 percent of the Manhattan taxi fleet is dieselized in combination with a 25-percent rate of PC dieselization. These results are shown graphically for the median, 13-ft, 100-ft and 300-ft roadway site positions in Figures 4-40 through 4-43, sequentially. In general, these curves display the same characteristics as the pollutant dump curves for Manhattan given in Section 4.1.1. The high levels shown for total exhaust particulates in the 1975 baseline year reflect a large contribution from precatalyst gasoline-powered LDV's using leaded fuel. The concentration characteristic at first decreases as catalyst control technology is implemented in new production vehicles and

Table 4-2. Urban Freeway Exhaust Particulate Concentrations at Selected Traffic Conditions, 1975 Baseline Year

Traffic Count (veh/hr)	Roadway Median		Distance From Edge of Roadway, Ft					
			13		100		300	
	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]
12,000	12.2	86.7	17.8	126.4	6.6	46.6	2.8	19.9
9,000	9.2	65.0	13.4	94.8	4.9	34.9	2.1	14.9
6,000	6.1	43.3	8.9	63.2	3.3	23.3	1.4	9.9
3,000	3.1	21.7	4.5	31.6	1.6	11.6	0.7	5.0

Fiftieth-percentile values, based on representative ψ characteristic (Figure 3-2), $\mu g/m^3$

[a]Diesel only exhaust emission contribution (LDV, LDT, HDV)

[b]Total mobile source exhaust emission contribution (diesel + gasoline LDV, LDT, HDV)

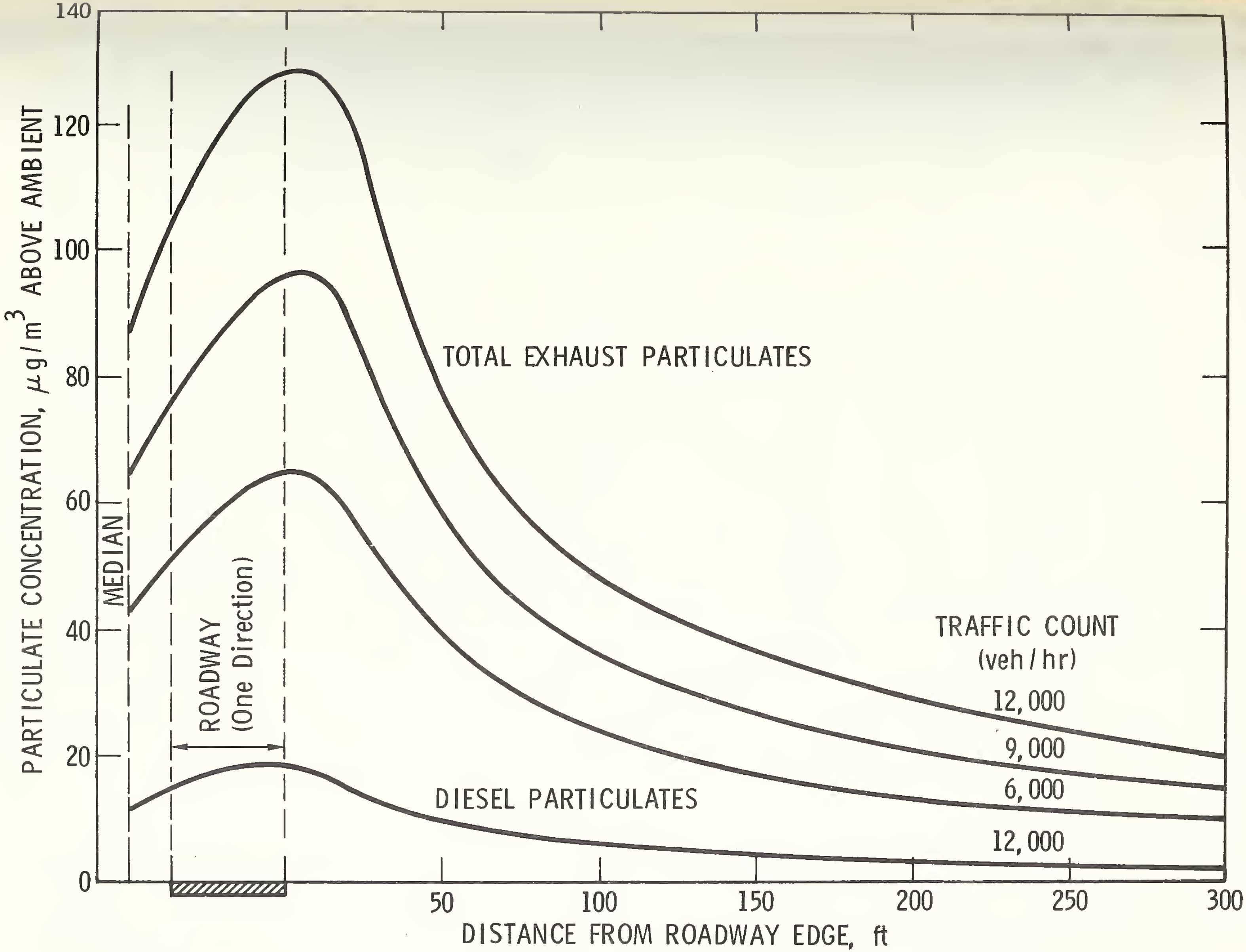

Figure 4-39. Urban Freeway Exhaust Particulate Concentrations, 1975 Baseline Year

Table 4-3. Urban Freeway Exhaust Particulate Concentrations at Peak Traffic Conditions

Dieselization Rate	Year	Roadway Median		Distance From Edge of Roadway, Ft					
				13		100		300	
		Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]
BC	1975	12.2	86.7	17.8	126.4	6.6	46.6	2.8	19.9
	1985	19.6	38.3	28.6	55.9	10.5	20.6	4.5	8.8
	1990	27.1	39.5	39.5	57.5	14.6	21.2	6.2	9.0
	2000	42.0	46.9	61.3	68.5	22.6	25.2	9.6	10.8
10%	1985	24.7	43.5	36.1	63.4	13.3	23.4	5.7	10.0
	1990	33.1	45.2	48.3	65.9	17.8	24.3	7.6	10.4
	2000	48.1	52.7	70.1	76.9	25.9	28.3	11.0	12.1
25%	1985	34.0	52.1	49.6	76.0	18.3	28.0	7.8	11.9
	1990	43.5	54.7	63.4	79.8	23.4	29.4	10.0	12.5
	2000	57.9	61.9	84.4	90.3	31.1	33.3	13.3	14.2
25% PC + 100% Taxis	1985	55.2	73.7	80.6	107.5	29.7	39.6	12.7	16.9
	1990	55.2	66.5	80.6	97.0	29.7	35.7	12.7	15.2
	2000	67.4	71.4	98.3	104.2	38.4	38.4	15.5	16.3

Fiftieth-percentile values based on generalized ψ profile (Figure 3-2), $\mu g/m^3$ above ambient, traffic count = 12,000 veh/hr.

PC = Passenger Cars

BC = Base Case (1% LDV, 0.2% LDT)

[a]Diesel only exhaust emission contribution (LDV, LDT, HDV)

[b]Total mobile source exhaust emission contribution (diesel + gasoline LDV, LDT, HDV)

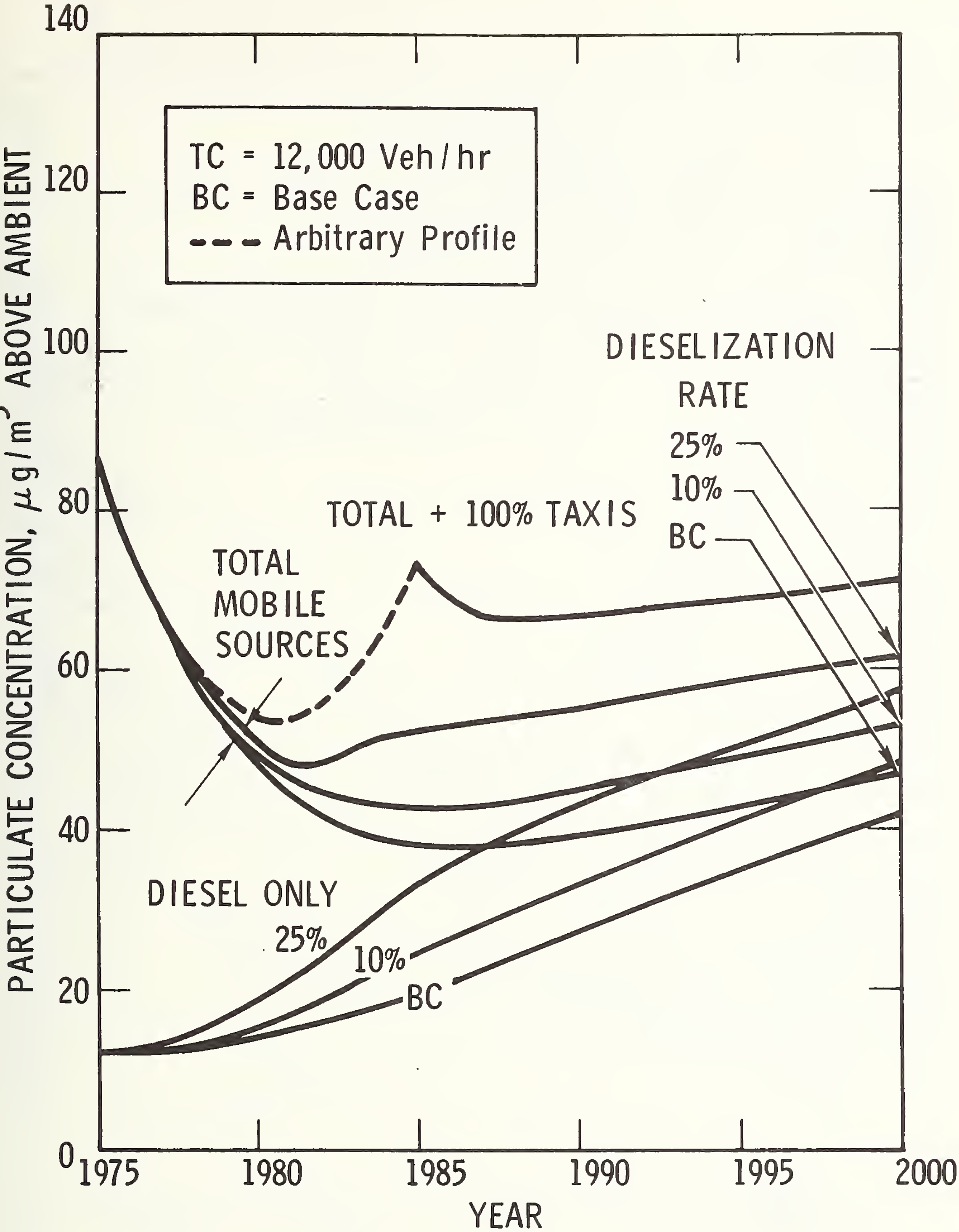

Figure 4-40. Urban Freeway Exhaust Particulate Concentrations, Median Position

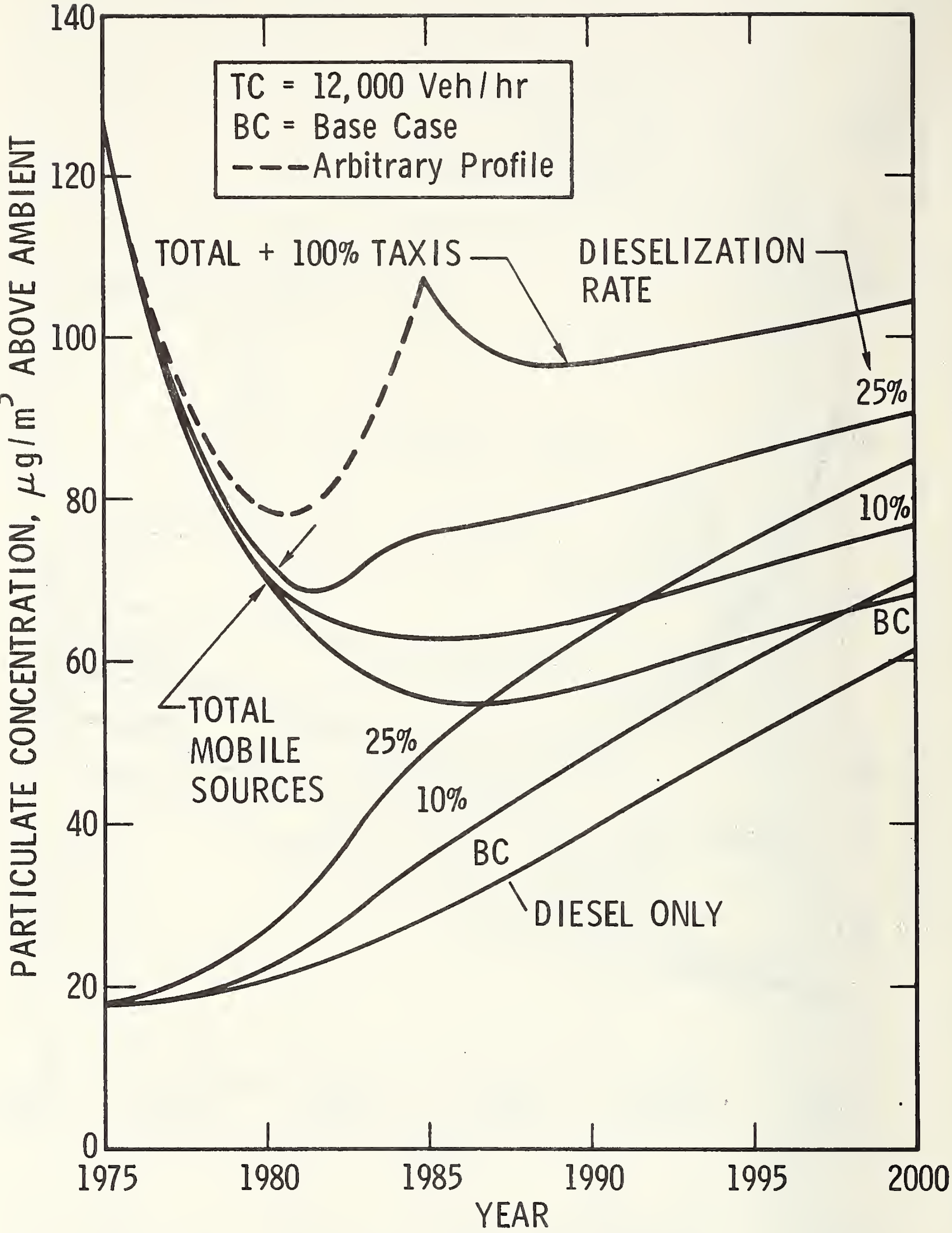

Figure 4-41. Urban Freeway Exhaust Particulate Concentrations, 13 Feet from Roadway Edge

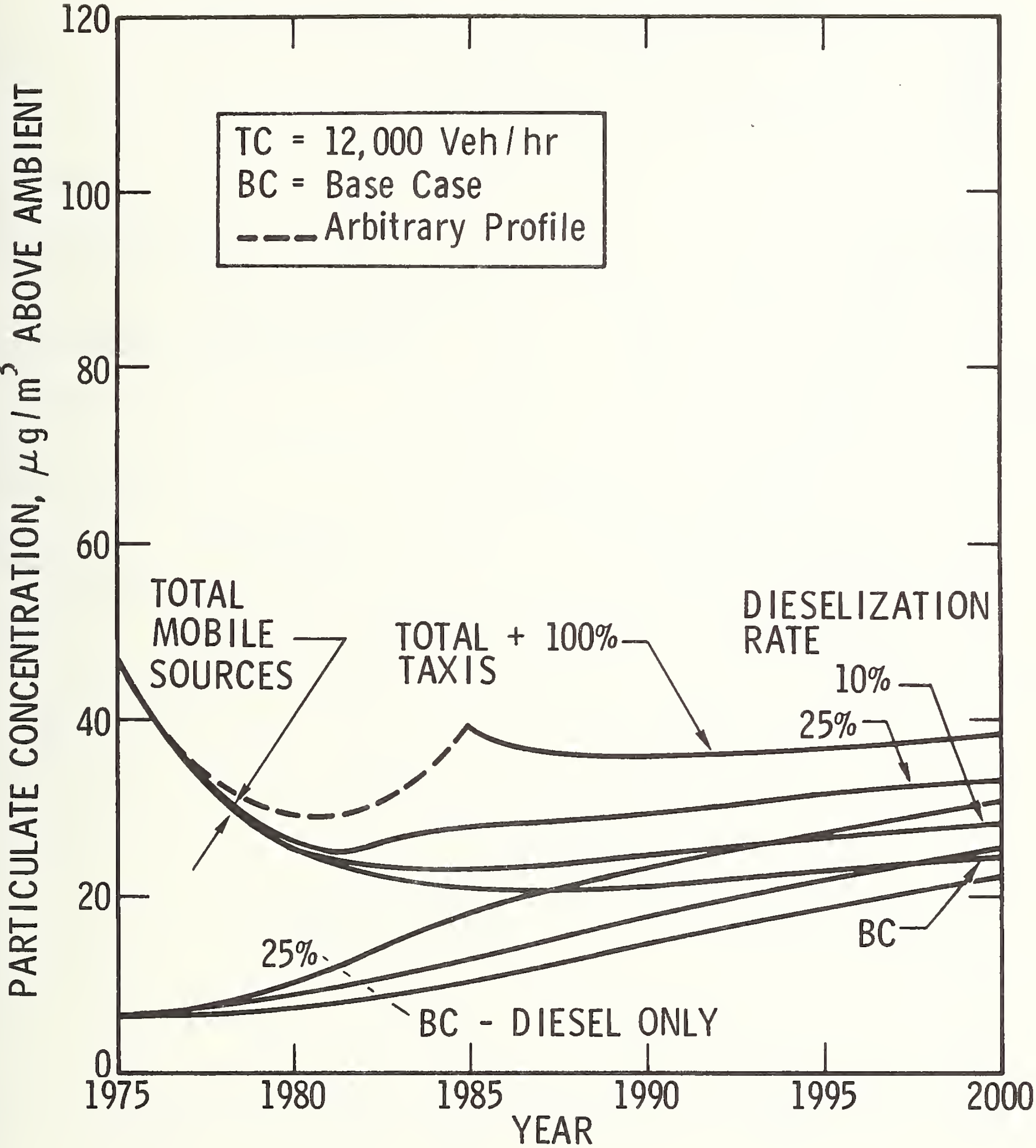

Figure 4-42. Urban Freeway Exhaust Particulate Concentrations, 100 Feet from Roadway Edge

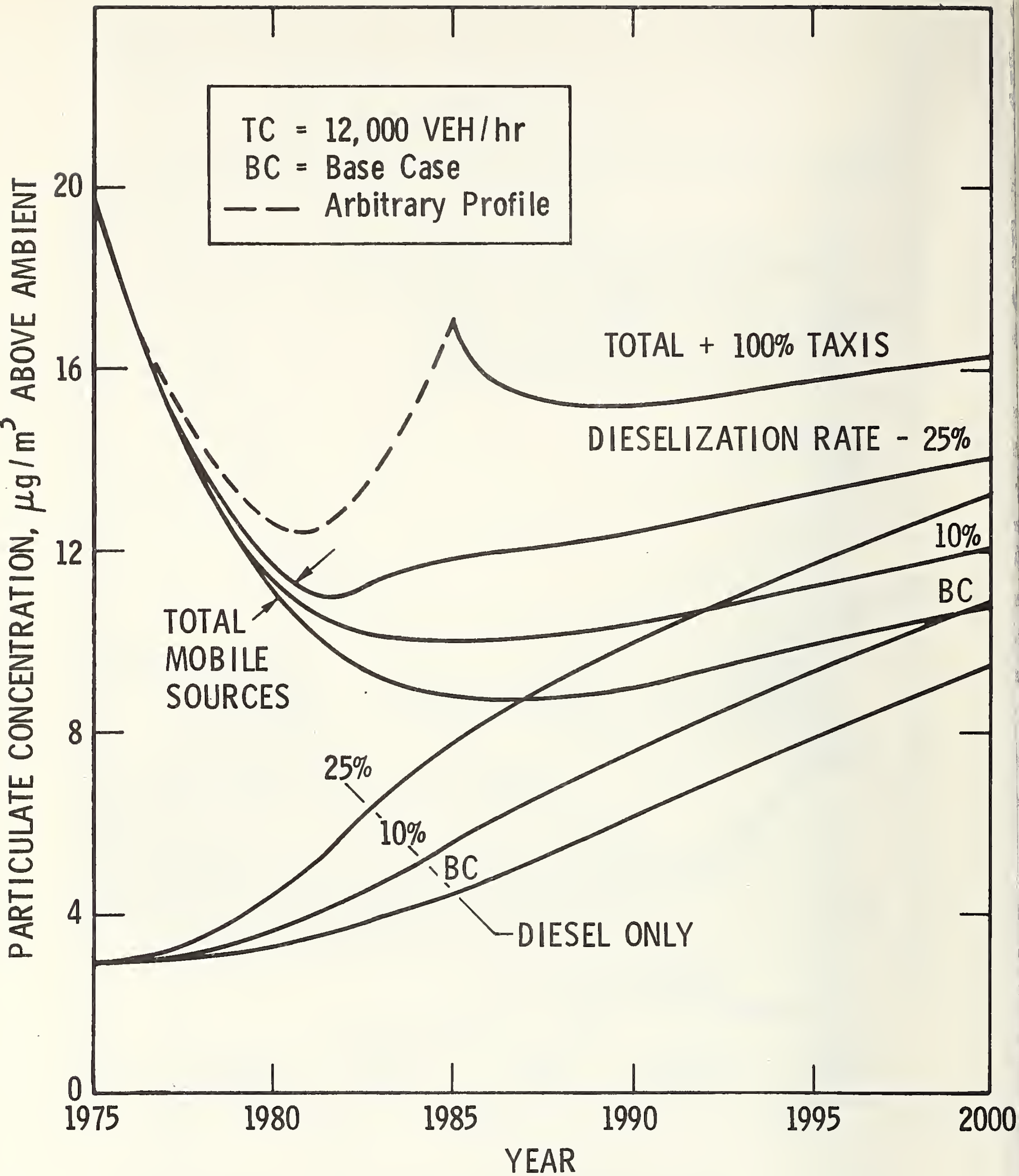

Figure 4-43. Urban Freeway Exhaust Particulate Concentrations, 300 Feet from Roadway Edge

then rises again in later years as an increasing number of diesel vehicles enter the fleet.

It should be noted that the particulate concentrations displayed in these tables and figures represent only the motor vehicle exhaust emission contribution to concentration level. The absolute or actual concentration in the urban freeway site is the sum of the motor vehicle effect and the background level of pollutant concentration as produced by other particulate emission sources.

Considering the purposes of this study, it is obviously desirable to estimate particulate concentration levels at the conditions for which the ambient air quality standards are defined. For particulates, the standards are set in terms of both a maximum 24-hour concentration in a given year and an annual geometric mean. The values for the 24-hour concentration are 260 and 150 $\mu g/m^3$, primary and secondary standards, respectively, and for the geometric mean, 75 and 60 $\mu g/m^3$, primary and secondary, respectively. The State of California specifies 100 and 60 $\mu g/m^3$ for the 24-hour and geometric mean values, respectively.

Strictly speaking, the determination of the 24-hour maximum concentration would require a data base of contiguous 24-hour concentration measurements over a period of a year. However, the data available to this study consists primarily of hourly average readings taken at selected intervals and periods of the day. On the other hand, most of the data (excluding the GM experiment which controlled traffic at a constant average speed) typically involved a broad range of traffic conditions, including rush hour peaks, midday traffic, and some early morning and late evening periods of low traffic density. Also, a wide range of micrometeorological conditions are represented in the data base. For the purpose of the calculation at hand, therefore, it seems reasonable to assume that the data-based ψ characteristics will be representative of 24-hour average conditions.

Projected values for the 24-hour maximum annual concentration were determined as follows. The appropriate ψ value for this case corresponds to the percentile

$$\left(1 - \frac{1}{365}\right) \times 100 = 99.73\%$$

This percentile value of ψ was estimated by extrapolating a plot of cumulative percent ψ vs ψ, using the GM data (the most extensive data base available). The ratio $(\psi_{99.73})/(\psi_{50})$ was established from this plot and was applied to the 50th-percentile ψ characteristics shown in Figure 3-2 to obtain $\psi_{99.73}$. The traffic count required for the concentration calculation was obtained from a 24-hour integration of traffic flow on an 8-lane urban freeway in Los Angeles (Ref. 4-4), and was established as 7850 veh/hr. This value is assumed to be representative of urban freeway conditions nationwide. Then, the 24-hour concentration was calculated from the product of the 99.73rd-percentile level of ψ, the 24-hour average traffic count, and the composite emission factor corresponding to the projection year and dieselization scenario under consideration (Manhattan statistics).

The annual geometric mean was taken as one-third of the annual maximum 24-hr concentration (Refs. 4-5, 4-6).

Results of the 24-hour maximum and annual geometric mean computations are shown in Table 4-4 for all study cases including the Manhattan 100-percent taxi dieselization scenario. The values here are referenced to the data-representative ψ characteristic in Figure 3-2 and, accordingly, are considered to portray a best estimate of urban freeway effects. For comparison, a similar set of calculations was executed using the ψ characteristic fitted to the extreme limits of the freeway data base. These values are presented in Table 4-5 as a worst-case estimate of urban freeway effects.

Referring to Table 4-4, it may be seen that relatively high levels are indicated for the median and roadway edge positions (as expected), although nowhere are the Federal primary standards exceeded by the motor vehicle exhaust emission contribution. It may be noted that the values for total particulate concentration are everywhere less than for the 1975 baseline year.

Table 4-4. Urban Freeway Exhaust Particulate Concentrations, Maximum 24-Hour and Annual Geometric Mean Values (Best Estimate)

Dieselization Rate	Year	Roadway Median				Distance From Roadway Edge, Ft											
						13				100				300			
		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates	
		24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual
BC	1975	21.0	7.0	148.8	49.6	27.1	9.0	191.8	64.0	10.7	3.6	76.1	25.4	7.0	2.3	49.6	16.5
	1985	33.6	11.2	65.7	21.9	43.3	14.4	84.8	28.8	17.2	5.7	33.6	11.2	11.2	3.7	21.9	7.3
	1990	46.5	15.5	67.6	22.6	60.0	20.0	87.3	29.1	23.8	7.9	34.6	11.5	15.5	5.2	22.6	7.5
	2000	72.2	24.1	80.6	26.9	93.0	31.0	103.9	34.6	36.9	12.3	41.2	13.7	24.1	8.0	26.9	9.0
10%	1985	42.5	14.2	74.6	24.9	54.7	18.2	96.2	32.1	21.7	7.2	38.2	12.7	14.2	4.7	24.9	8.3
	1990	56.8	19.0	77.6	25.9	73.4	24.4	100.0	33.3	29.1	9.7	39.7	13.2	19.0	6.3	25.9	8.6
	2000	82.6	27.6	90.4	30.1	106.4	35.5	116.7	38.8	42.2	14.1	46.2	15.4	27.6	9.2	30.1	10.1
25%	1985	58.4	19.5	89.5	29.8	75.2	25.1	115.4	38.5	29.8	9.9	45.8	15.3	19.5	6.5	29.8	9.9
	1990	74.6	24.9	94.0	31.4	96.3	32.1	121.1	40.3	38.2	12.7	48.0	16.0	24.9	8.3	31.4	10.4
	2000	99.4	33.2	106.3	35.4	128.1	42.7	137.1	45.6	50.8	16.9	54.3	18.1	33.2	11.0	35.4	11.8
25%PC + 100% Taxis	1985	95.0	31.7	126.5	42.2	122.4	40.8	163.2	54.5	48.6	16.2	64.7	21.6	31.7	10.6	42.2	14.1
	1990	95.0	31.7	114.2	38.1	122.4	40.8	147.2	49.0	48.6	16.2	58.4	19.4	31.7	10.6	38.1	12.7
	2000	115.7	38.6	122.6	40.9	149.1	49.7	158.1	52.6	59.2	19.7	62.7	20.8	38.6	12.9	40.9	13.6

Values referenced to representative ψ characteristic (Figure 3-2), $\mu g/m^3$ above ambient, traffic count = 7850 veh/hr.

TSP Air Quality Standards

	24-Hr	Annual Geometric Mean
Federal Primary/Secondary	260/150	75/60
California	100	60

Table 4-5. Urban Freeway Exhaust Particulate Concentrations, Maximum 24-Hour and Annual Geometric Mean Values (Worst-Case Estimate)

Dieselization Rate	Year	Roadway Median				Distance From Roadway Edge, Ft											
						13				100				300			
		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates	
		24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual
BC	1975	28.5	9.5	201.7	67.2	33.6	11.2	238.1	79.3	19.1	6.4	135.6	45.2	14.9	5.0	105.9	35.3
	1985	45.6	15.2	89.1	29.7	53.8	17.9	105.2	35.1	30.7	10.2	60.0	20.0	23.9	8.0	46.8	15.6
	1990	63.1	21.0	91.9	30.6	74.5	24.8	108.4	36.1	42.5	14.1	61.8	20.6	33.1	11.0	48.2	16.1
	2000	97.8	32.6	109.2	36.4	115.5	38.5	129.0	43.0	65.8	21.9	73.5	24.4	51.4	17.1	57.3	19.1
10%	1985	57.6	19.2	101.2	33.7	68.0	22.6	119.5	39.8	38.7	12.9	68.1	22.7	30.2	10.0	53.1	17.7
	1990	77.1	25.7	105.3	35.1	91.0	30.3	124.2	41.4	51.9	17.3	70.8	23.6	40.4	13.5	55.2	18.4
	2000	111.9	37.3	122.7	40.9	132.1	44.0	144.8	48.3	75.3	25.1	82.5	27.4	58.7	19.6	64.3	21.4
25%	1985	79.1	26.4	121.3	40.4	93.4	31.1	143.2	47.7	53.2	17.8	81.6	27.2	41.5	13.8	63.7	21.2
	1990	101.2	33.7	127.4	42.5	119.5	39.8	150.3	50.1	68.1	22.7	85.7	28.5	53.1	17.7	66.8	22.3
	2000	134.7	44.9	144.1	48.0	159.0	53.0	170.1	56.7	90.6	30.2	96.9	32.3	70.7	23.6	75.6	25.2
25% PC + 100% Taxis	1985	128.7	42.9	171.6	57.2	151.9	50.6	202.6	67.5	86.6	28.9	115.4	38.5	67.5	22.5	90.0	30.0
	1990	128.7	42.9	154.9	51.6	151.9	50.6	182.8	60.9	86.6	28.9	104.1	34.7	67.5	22.5	81.2	27.1
	2000	156.9	52.3	166.3	55.4	185.2	61.7	196.2	65.4	105.4	35.2	111.7	37.3	82.3	27.4	87.2	29.1

Values referenced to data base extreme ψ characteristic (Figure 3-2), $\mu g/m^3$ above ambient, traffic count = 7850 veh/hr.

TSP Air Quality Standards

	24-Hr	Annual Geometric Mean
Federal Primary/Secondary	260/150	75/60
California	100	60

The peak concentrations occur at the 13-ft position where the California 24-hr standard of 100 $\mu g/m^3$ is exceeded for the base case (BC) dieselization rate in the years 1975 and 2000, for the 10-percent dieselization rate in the year 2000, and for all projection years at the 25-percent dieselization rate. At the median position, the California 24-hr standard of 100 $\mu g/m^3$ is exceeded only in the 1975 base case and for the 25-percent dieselization case in the year 2000 (Manhattan taxi dieselization is excluded in this comparison). At the 100- and 300-ft positions, which are of principal interest from the standpoint of longer term human exposure, the total concentrations are generally less than 30 percent of the primary Federal standard.

Referring to Table 4-5, which shows comparable results based on the ψ characteristic fitted to the extreme limits of the data base, it may again be seen that total concentration levels are everywhere less than for the baseline year of 1975. The Federal 24-hour primary standard of 260 $\mu g/m^3$ is not exceeded by the motor vehicle exhaust emission contribution for any of the analysis conditions considered. In this case, however, the secondary 24-hour and annual mean standards are exceeded at the 13-ft position for the 1975 base case and the 25-percent and Manhattan taxi dieselization scenarios. No standard is exceeded at distances of 100 and 300 ft from the roadway; the levels here are generally less than 45 percent of the Federal primary standards. At the median and 13-ft locations, the California 24-hour standard of 100 $\mu g/m^3$ is approached or exceeded for all analysis cases, including the base case. As discussed in Section 3.2.1, no long-term human exposure situations are identified for the 13-ft position; it is included in the analysis to permit comparisons to be made with previous studies that have emphasized exposure levels very near the edge of the roadway.

One such study was conducted by PEDCo Environmental, Inc. (Ref. 4-5). The PEDCo study based its analysis of roadway concentrations on conditions at a position 13 ft from the roadway edge. A comparison of results between this study and PEDCo indicates that at equivalent traffic count conditions, the present analysis shows significantly lower concentration levels at the 13-ft position and would predict relatively higher concentration levels at the more remote positions had the PEDCo analysis been extended to these locations. This subject is more fully discussed in Appendix E.

Because the data in Tables 4-4 and 4-5 represent only the motor vehicle exhaust emission contribution to the particulate concentration level, the absolute or actual concentrations in the urban freeway site will be higher than the values shown by the amount of the background particulate count. Therefore, although the concentration values indicated are well below the Federal primary standard for the roadway site positions of primary interest, high areawide background count conditions in metropolitan regions such as Manhattan may make these levels a matter of concern. This and other environmental issues pertaining to the urban freeway results are examined in Section 5.

4.2.1.2 Odor Effects

Odor effects for the urban freeway were determined using the methodology described in Section 3.1.2. The basic relationship for estimating diesel odor intensity level Damb is

$$\text{Damb} = \text{Dmode} + \frac{2 - \log \text{DR}}{\log 2}$$

where DR is the diesel exhaust dilution ratio and Dmode is the D-number for diesel exhaust diluted 100:1, for a specific operating mode (Ref. 4-7). A value of Dmode = 3.2 was selected as being representative of urban freeway traffic conditions nationwide.

At field test conditions, the dilution ratio may be obtained from CO, sulfate, or tracer gas receptor readings and from a calculated average value of the test gas concentration in the test-traffic vehicle exhaust. For a given receptor

$$(\text{DR})\text{test} = \frac{\text{concentration in test-traffic vehicle exhaust}}{\text{concentration at receptor}}$$

Assuming the same vehicle class distribution, and the same urban freeway meteorology, the dilution ratio for diesel exhaust in a projected dieselized fleet may be obtained from

$$(DR)proj = \frac{(DR)test}{f} \times \frac{TC_{test}}{TC_{proj}} = \frac{1}{f}\left[\frac{ConcExh}{\psi \times TC \times EF}\right]_{test} \times \frac{TC_{test}}{TC_{proj}}$$

where (DR)proj is the projected dilution ratio, f is the fraction of vehicles in the freeway traffic flow that are diesel-powered (all vehicle classes), and TC is the traffic count. Using 95th-percentile values of ψ given in Figure 3.2 and taking f values up to 0.25, it is found that the computed odor effects are negligible for all projection cases and roadway positions. These data therefore suggest that diesel odor will not be a significant problem in the urban freeway site.

This analysis probably understates the odor effects, however, since the data bases used were largely 1-hour average results, and odor effects may be strongly influenced by short-duration, localized concentrations at higher levels. Also, localized groupings of vehicles may occur in which the fraction of diesel vehicles is substantially higher than the areawide average. In order to assess these possible effects, a worst-case odor analysis was performed, using an f value of unity (100-percent diesels), and the highest measured value of concentration in the urban freeway data base.* These factors combine to yield the minimum value of (DR)proj, the highest computed value of Damb, and hence the greatest odor effect. This approach yielded a dilution ratio of 320 and a value of Damb = 1.5.

The lowest Damb tested in a study to determine public response to diesel exhaust odor (Ref. 4-8) was 2.0. Fifty-six percent of the subjects tested evaluated this odor level as "unpleasant or worse." Since the 1.5 Damb level represents about 70 percent of the concentration of Damb = 2.0, it would be expected that the number of negative responses to the 1.5 Damb level would

*Median roadway position, I-280 data base.

be less than reported for 2.0. However, the magnitude of this reduction cannot be estimated.

In summary, the results of the odor analysis for the urban freeway indicate that, on a nominal-diesel-mix basis, the odor effects related to LDV dieselization will not be a problem. However, localized, high-level exhaust concentrations may occur, producing odor effects regarded as unpleasant or worse by about 50 percent of the public.

4.2.2 Street Canyon

4.2.2.1 Particulates

As described in Section 3.3.3, particulate concentrations in the street canyon were calculated using two bases: (1) the generalized 50th-percentile profile of ψ versus height, representing frequently recurring conditions applicable to all urban area CBD's, and (2) the 50th-percentile ψ value taken from the continuous-reading street level probe at East 45th Street in a worst-case metropolitan geometry.

Addressing first the results obtained using the generalized profile of ψ versus height, Table 4-6 presents, for the baseline year of 1975, calculated values of particulate concentrations at different street canyon elevations (Manhattan statistics*). Values are shown for a range of traffic counts up to 2000 vehicles per hour, an approxixmate upper limit indicated by traffic data given in the street canyon field studies. These data are plotted in Figure 4-44. It may be seen that for the baseline year, particulates from gasoline vehicles predominate, reflecting the widespread use of leaded fuel and the very limited penetration of diesel vehicles at that time.

Results projected through the year 2000 at these street canyon elevations are shown for the base case, 10-percent and 25-percent dieselization scenarios in Table 4-7 (traffic count = 2000 veh/hr). Included in this table are results for the Manhattan taxi scenario, which combines 25-percent passenger car dieselization with 100-percent taxicab dieselization. Here

*All values in this section are based on composite particulate emission factors for Manhattan as developed from the areawide pollutant dump analysis (EF = $\sum$ Dump/ $\sum$VMT).

Table 4-6. Street Canyon Exhaust Particulate Concentrations at Selected Traffic Conditions, Representative Meteropolitan Geometry, 1975 Baseline Year

	Height Above Street, ft									
	6		15		30		60		120	
Traffic Count (Veh/Hr)	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]
2000	4.3	30.7	3.9	27.7	3.1	22.3	2.3	16.2	1.2	8.4
1500	3.3	23.0	2.9	20.8	2.4	16.7	1.7	12.2	0.9	6.3
1000	2.2	15.4	2.0	13.8	1.6	11.1	1.2	8.1	0.6	4.2
500	1.1	7.7	1.0	6.9	0.8	5.6	0.6	4.1	0.3	2.1

Values based on generalized ψ profile (Figure 3-2), $\mu g/m^3$ above ambient

[a]Diesel exhaust emission contribution (LDV, LDT, HDV)

[b]Total mobile source exhaust emission contribution (Diesel + gasoline LDV, LDT, HDV)

Table 4-7. Street Canyon Exhaust Particulate Concentrations at Peak Traffic Conditions, Representative Metropolitan Geometry

Dieselization Rate	Year	Height Above Street, ft					
		6		30		90	
		Diesel[a]	Total[b]	Diesel[a]	Total[b]	Diesel[a]	Total[b]
BC	1975	4.3	30.7	3.1	22.3	1.7	12.0
	1985	6.9	13.6	5.0	9.8	2.7	5.3
	1990	9.6	14.0	7.0	10.1	3.8	5.5
	2000	14.9	16.6	10.8	12.1	5.8	6.5
10%	1985	8.8	15.4	6.4	11.2	3.4	6.0
	1990	11.7	16.0	8.5	11.6	4.6	6.3
	2000	17.0	18.7	12.4	13.5	6.7	7.3
25%	1985	12.0	18.5	8.7	13.4	4.7	7.2
	1990	15.4	19.4	11.2	14.1	6.0	7.6
	2000	20.5	21.9	14.9	15.9	8.0	8.6
25% PC	1985	19.6	26.1	14.2	18.9	7.7	10.2
+	1990	19.6	23.6	14.2	17.1	7.7	9.2
100% Taxis	2000	23.9	25.3	17.3	18.4	9.4	9.9

Fiftieth-percentile values, based on generalized ψ profile (Figure 3-2), $\mu g/m^3$ above ambient; traffic count, 2000 veh/hr

[a]Diesel exhaust emission contribution (LDV, LDT, HDV)

[b]Total mobile source exhaust emission contribution (Diesel + Gasoline LDV, LDT, HDV)

HEIGHT ABOVE STREET, FT

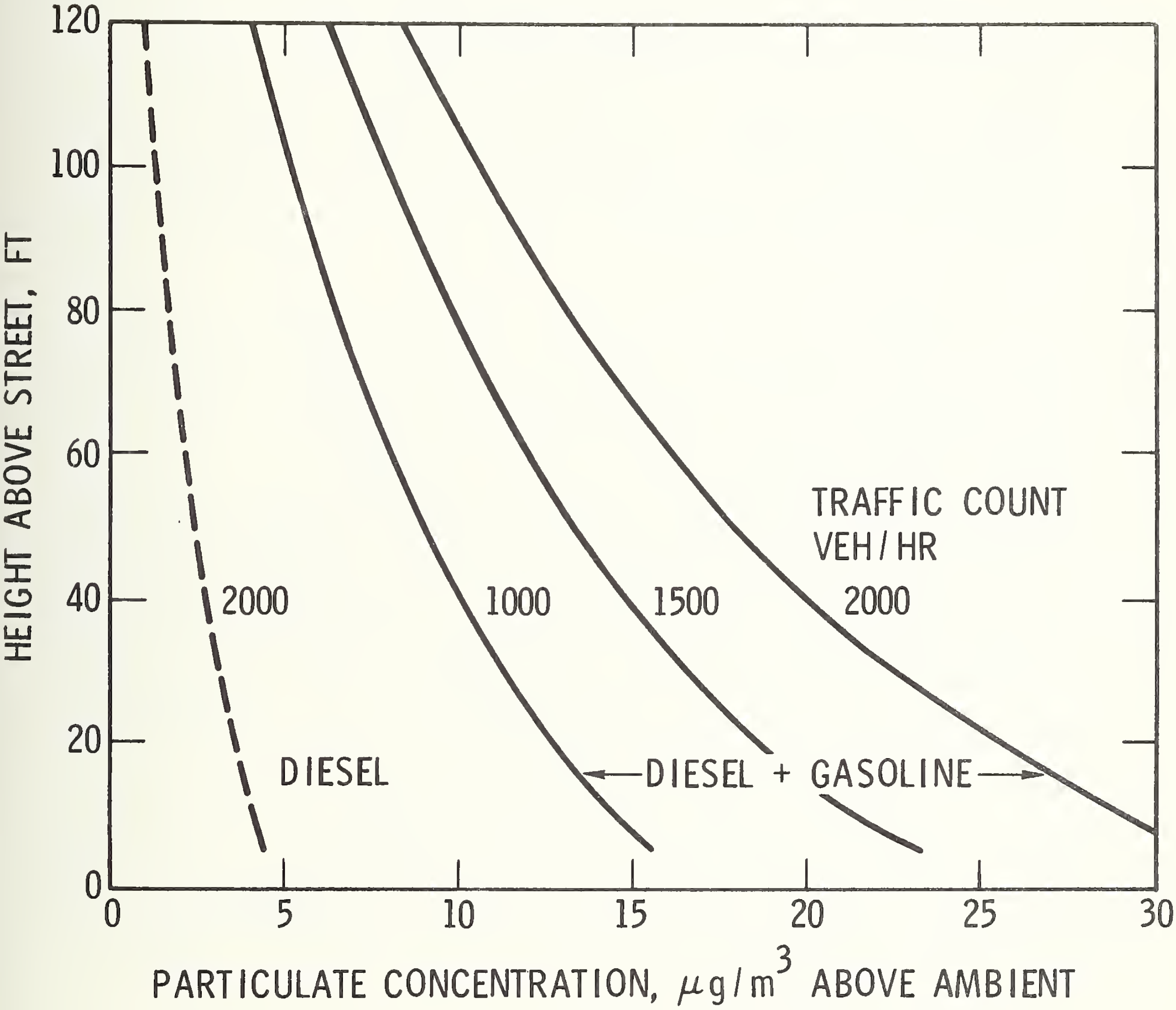

Figure 4-44. Street Canyon Exhaust Particulate Concentrations, 1975 Baseline Year

the adverse assumption* on the model year make-up of the taxi fleet has been adopted (see Section 4.1.1.2).

The values shown for the 6-ft height are taken to represent the quality of the atmosphere exposed to pedestrians and motorists and ventilated into the ground flood of adjacent buildings. Values shown for the 30- and 90-ft elevations are considered to represent ventilation air concentration levels at the second through eighth floors. Results for each height are presented graphically in Figures 4-45, 4-46, and 4-47, respectively. It may be seen that the curves reflect the shape of the Manhattan dump characteristics given in Section 4.1.1.

It should be noted that the particulate concentrations presented here represent only the contribution of the street canyon traffic; exhaust emission effects from other sources must be added to these values to obtain the total particulate concentration in the canyon site.

Projected results based on the curbside probe at East 45th Street in Manhattan are shown in Table 4-8 and in Figure 4-48. These results are higher (by a factor of approximately 1.6) than the street level concentrations projected on the basis of the generalized street canyon correlation. This result directly reflects the high concentration level of the baseline year CO measurements at the Manhattan 45th Street probe location.

As discussed earlier, the rationale used in this study considers that values of ψ at the 50th-percentile level provide a reasonable estimate of pollutant concentrations that occur frequently. It is pertinent also to examine pollutant concentration levels at conditions corresponding to maximum 24-hour and annual geometric mean ambient air quality standards.

Projected values for the 24-hour maximum concentration were determined as follows. The appropriate ψ value for this case corresponds to the percentile

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*Vehicle age distribution is taken to be the same as Manhattan's passenger car fleet.

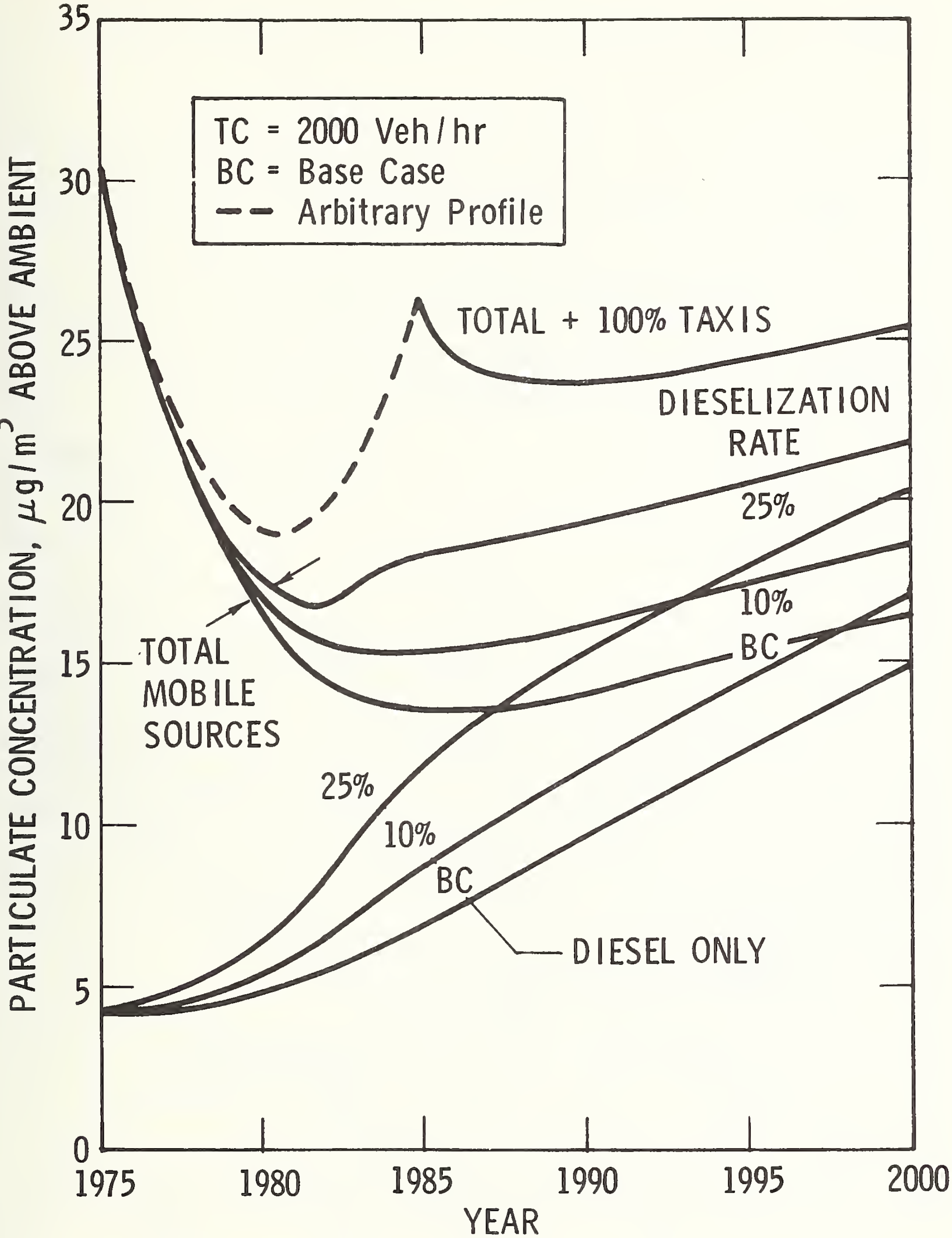

Figure 4-45. Street Canyon Exhaust Particulate Concentrations, 6 Feet Above Street Level

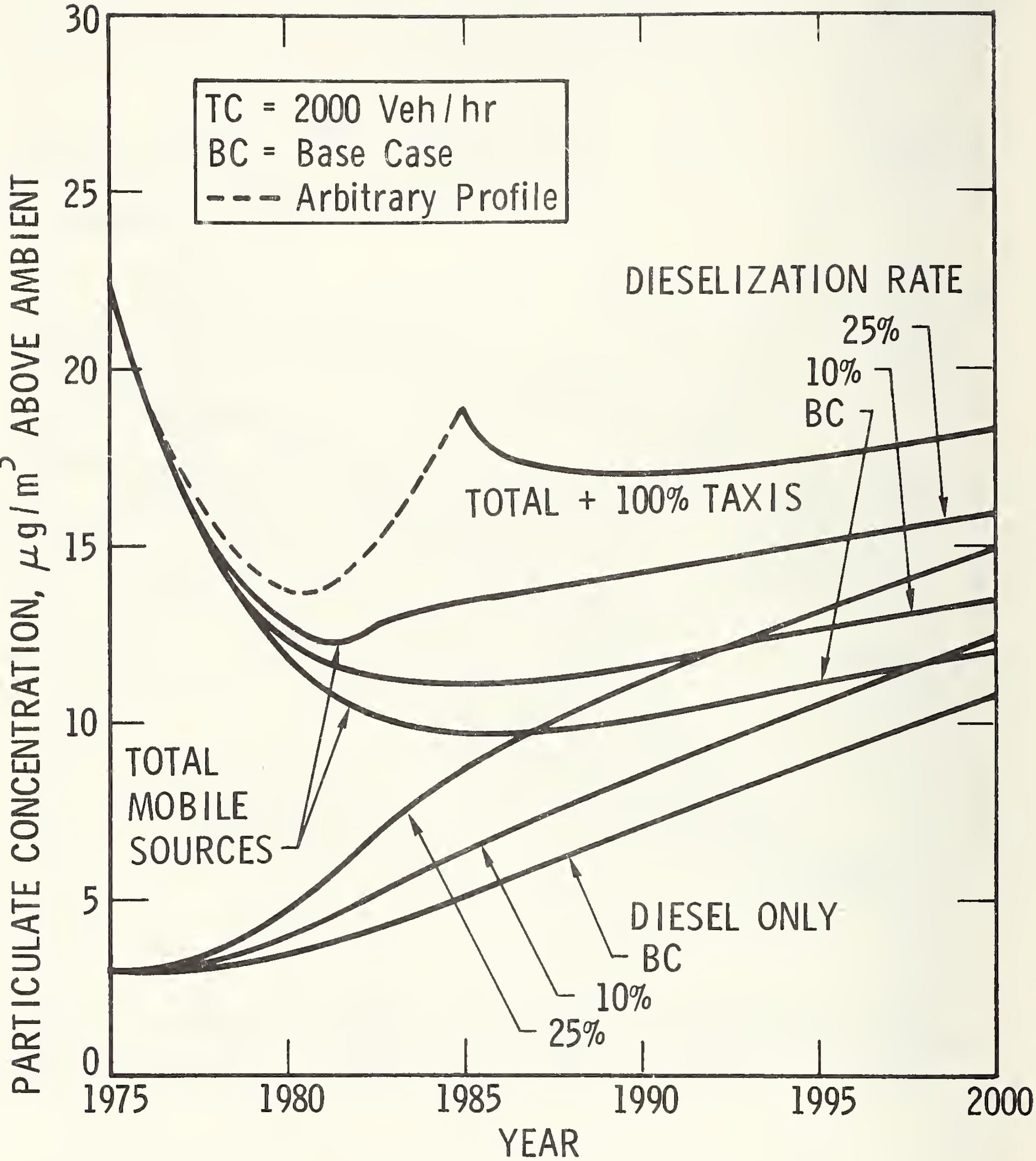

Figure 4-46. Street Canyon Exhaust Particulate Concentrations, 30 Feet Above Street Level

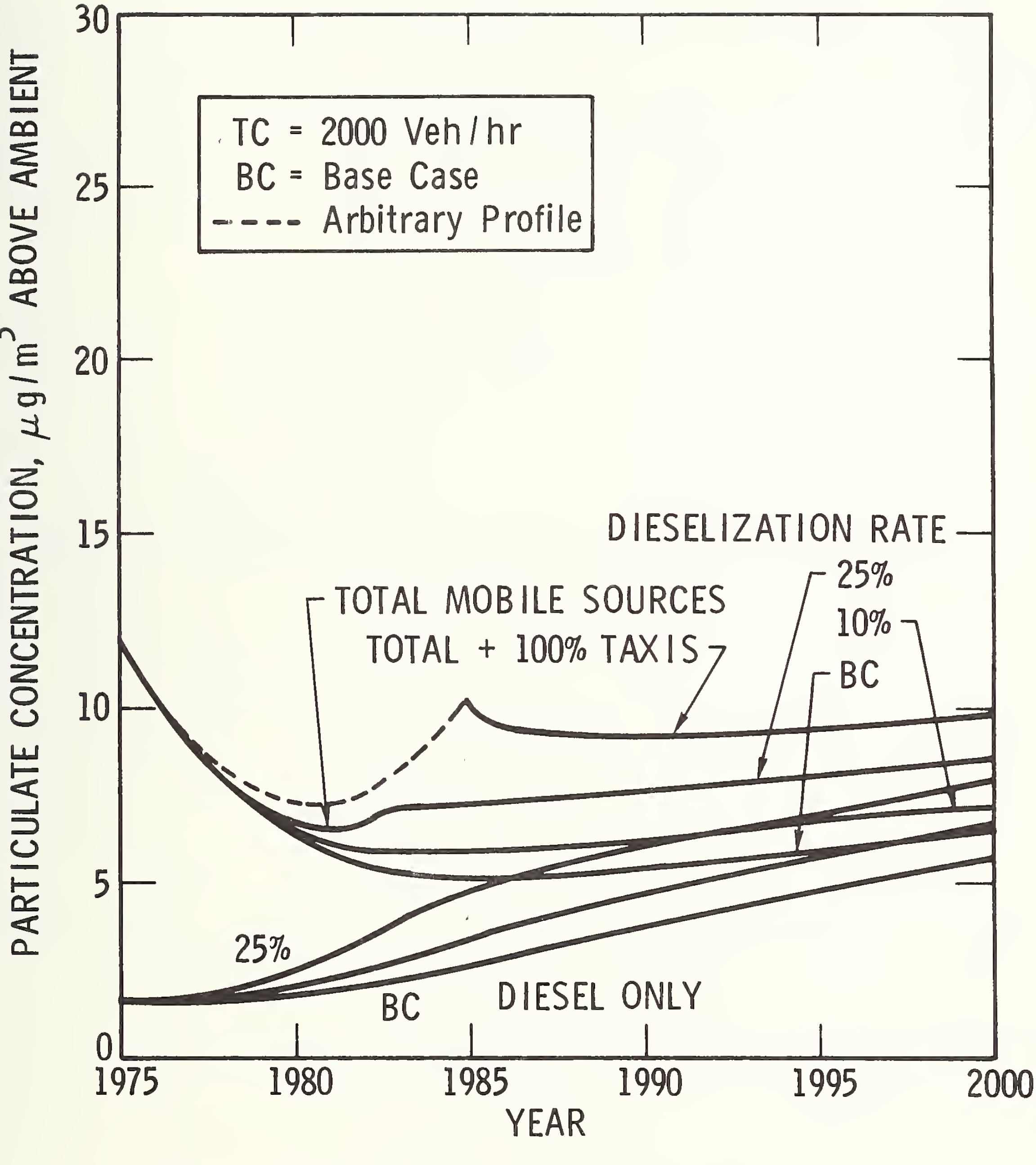

Figure 4-47. Street Canyon Exhaust Particulate Concentrations, 90 Feet Above Street Level

Table 4-8. Street Canyon Exhaust Particulate Concentrations at Peak Traffic Conditions, Worst-Case Metropolitan Geometry

Dieselization Rate	Year	Particulate Concentration ($\mu g/m^3$ above ambient) Diesel[a]	Total[b]
BC	1975	6.9	48.9
	1985	11.0	21.6
	1990	15.3	22.2
	2000	23.7	26.5
10%	1985	14.0	24.5
	1990	18.7	25.5
	2000	27.1	29.7
25%	1985	19.2	29.4
	1990	24.5	30.9
	2000	32.6	34.9
25% PC + 100% Taxis	1985	31.2	41.6
	1990	31.2	37.5
	2000	38.0	40.3

Based on fiftieth-percentile CO concentrations at curbside receptor at 110 East 45th Street, Manhattan

[a]Diesel exhaust emission contribution (LDV, LDT, HDV)

[b]Total mobile source exhaust emission contribution (Diesel + Gasoline LDV, LDT, HDV)

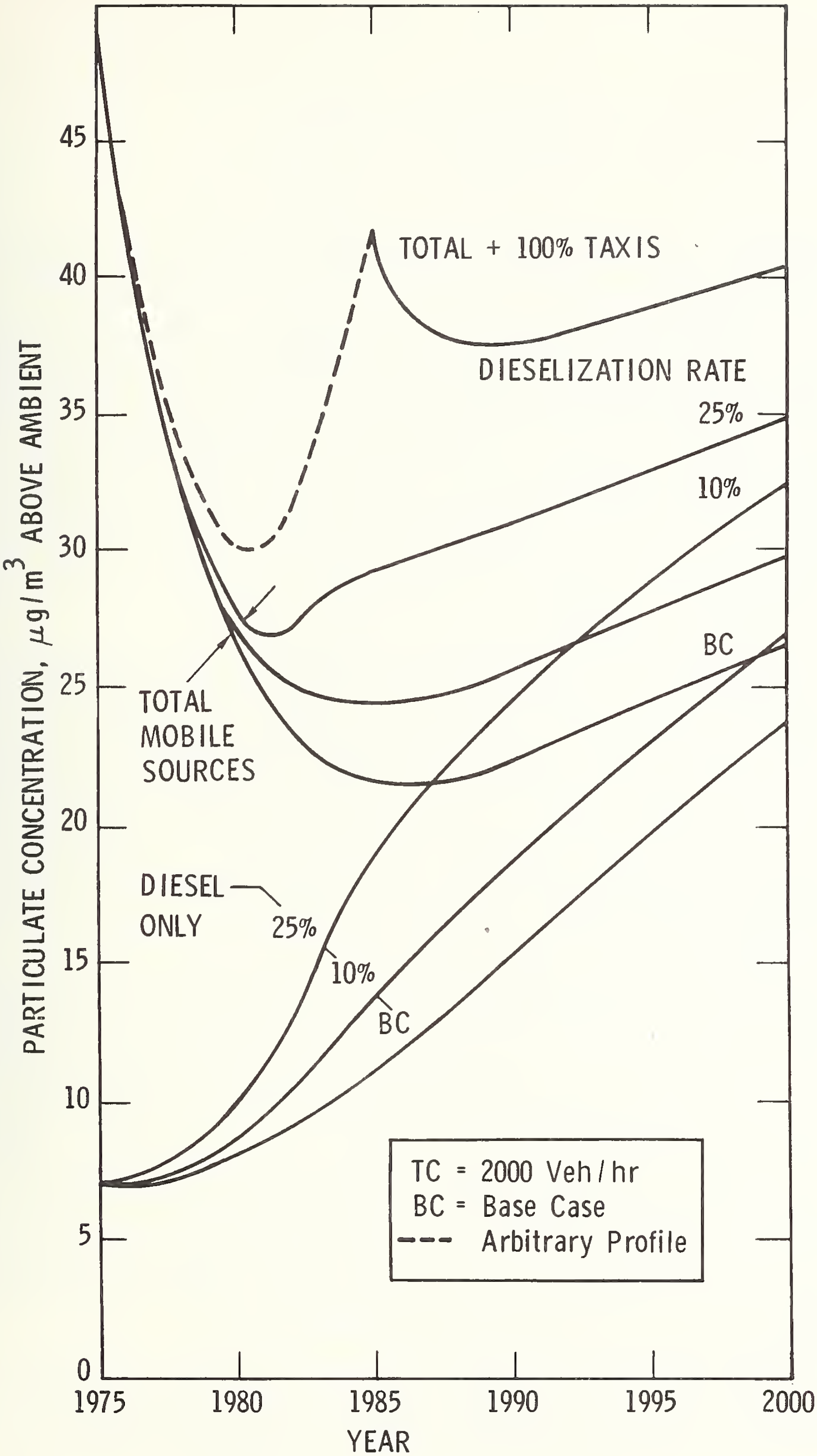

Figure 4-48. Street Canyon Exhaust Particulate Concentrations, Worst-Case Metropolitan Geometry

$$\left(1 - \frac{1}{365}\right) \times 100 = 99.73\%$$

and was obtained by extrapolating a plot of cumulative percent ψ versus ψ, using all of the values developed from the St. Louis field study. A 24-hour average traffic count of 936 veh/hr (22,500 vehicles per day) was established from traffic data given for the Broadway street canyon (Ref. 4-9). This count was assumed to be representative of average street canyon conditions nationwide. The 24-hour concentration, then, was obtained from the product of the 99.73rd-percentile level of ψ, the traffic count, and the composite emission factor corresponding to the projection year and dieselization scenario under consideration (Manhattan statistics).

Results obtained using the generalized street canyon ψ profile as a base are shown in Table 4-9 for the 25-percent dieselization scenario and the 100-percent diesel taxi scenario. Included in this table are values for the annual geometric mean, which was computed as one-third of the 24-hour maximum (see discussion in Section 4.2.1). It may be seen that there is no case in which any of the standards for total suspended particulates are exceeded by the vehicle exhaust contribution.

Results of a similar analysis at street level, based on the curbside receptor at East 45th Street in Manhattan, are shown in Table 4-10. The 99.73rd-percentile CO value for this receptor was determined from long-term continuous records, as described in Section 3.3.2. This table shows that the Federal 24-hour primary standard of 260 $\mu g/m^3$ is not exceeded by the motor vehicle particulate contribution. Values of over 100 $\mu g/m^3$ (the California 24-hour standard) are exceeded in the year 2000 for the case of 25-percent dieselization of the LDV fleet, and in all post-1984 years for the case of the additional dieselization of the Manhattan taxicab fleet.

It should be emphasized that the values shown in Tables 4-9 and 4-10 represent only the motor vehicle exhaust emission contribution to particulate concentration; to these must be added the background count in order to obtain the absolute or actual levels of concentration. Thus, although the

Table 4-9. Street Canyon Exhaust Particulate Concentrations, Representative Metropolitan Geometry, Maximum 24-Hour and Annual Geometric Mean Values

Dieselization Rate	Year	Height Above Street, Ft.											
		6				30				90			
		Diesel Particulates		Total Particulates		Diesel Particulates		Total Particulates		Diesel Particulates		Total Particulates	
		24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual
25%	1985	21.3	7.1	32.5	10.8	17.1	5.7	26.2	8.8	10.3	3.4	15.7	5.2
	1990	27.2	9.0	34.1	11.4	21.9	7.3	27.7	9.2	13.1	4.4	16.5	5.5
	2000	36.2	12.0	38.6	12.9	29.1	9.7	31.2	10.4	17.4	5.8	18.7	6.2
25% PC +	1985	34.5	11.5	46.0	15.3	27.9	9.3	37.1	12.4	16.7	5.6	22.3	7.4
100% Total	1990	34.5	11.5	41.5	13.8	27.9	9.3	33.5	11.2	16.7	5.6	20.1	6.7
	2000	42.1	14.0	44.6	14.9	33.9	11.3	36.0	12.0	20.4	6.8	21.6	7.2

Values based on St. Louis field study data, $\mu g/m^3$ above ambient.

TSP Air Quality Standards

	24-Hr	Annual Geometric Mean
Federal Primary/Seconary	260/150	75/60
California	100	60

Table 4-10. Street Canyon Exhaust Particulate Concentrations, Worst-Case Metropolitan Geometry Maximum 24-Hour and Annual Geometric Mean Values (Street Level)

Dieselization Rate	Year	Diesel Particulates ($\mu g/m^3$ Above Ambient)		Total Particulates ($\mu g/m^3$ Above Ambient)	
		24-Hour	Annual	24-Hour	Annual
25%	1985	59.4	19.8	91.1	30.4
	1990	76.0	25.3	95.7	31.9
	2000	101.2	33.7	108.2	36.1
25% PC + 100% Taxis	1985	96.7	32.2	128.9	43.0
	1990	96.7	32.2	116.3	38.8
	2000	117.8	39.3	124.9	41.6

Values based on Manhattan East 45th Street probe data

TSP Air Quality Standards

	24-Hour	Annual Geometric Mean
Federal Primary/Secondary	260/150	75/60
California	100	60

vehicle contributions are well below the Federal primary standard, the relatively high background concentration in urban areas such as Manhattan may well make these values a matter of concern. Environmental issues pertaining to those results are discussed in Section 5.

4.2.2.2 Odor Effects

Odor effects for the street canyon case were determined using the methodology described in Section 3.1.2. The basic relationship for estimating diesel odor intensity level Damb is

$$\text{Damb} = \text{Dmode} + \frac{2 - \log \text{DR}}{\log 2}$$

where DR is the diesel exhaust dilution ratio and Dmode is the D-number for diesel exhaust diluted 100:1, for a specific operating mode (Ref. 4-7). A value of Dmode = 3.5 was selected as being representative of street canyon traffic conditions nationwide.

At field test conditions, the dilution ratio is obtained from CO receptor readings and from a calculated value of CO concentraion in the vehicle exhaust at test traffic conditions. For a given receptor

$$(\text{DR})\text{test} = \frac{\text{CO concentration in test-traffic vehicle exhaust}}{\text{CO concentration at receptor}}$$

Assuming the same traffic count/vehicle class distribution, and the same street canyon meteorology, the dilution ration for diesel exhaust in a projected dieselized fleet may be obtained from

$$(\text{DR})\text{proj} = \frac{(\text{DR})\text{test}}{f} \times \frac{\text{TC}_{\text{test}}}{\text{TC}_{\text{proj}}} = \frac{1}{f}\left[\frac{\text{Conc Exh}}{\psi \times \text{TC} \times \text{EF}}\right]_{\text{test}} \times \frac{\text{TC}_{\text{test}}}{\text{TC}_{\text{proj}}}$$

where (DR) proj is the projected dilution ratio, f is the fraction of vehicles in the street canyon traffic flow that are diesel powered (all vehicle classes), and TC is the traffic count. Using 95th-percentile values of the hourly CO data at various test receptors and taking f values up to 0.25, it is found that the odor effects are negligible for all projection cases. These data therefore suggest that diesel odor will not be a significant problem in the street canyon site.

The preceding analysis probably understates the odor effects, however, since the CO data base used were one-hour average results, while odor may be strongly influenced by short duration, localized exhaust concentrations at higher levels. Also, the fraction of diesels in a specific vehicle mix may be higher than the areawide average. In order to assess these possible effects, a worst-case odor analysis was performed, using the highest single CO test reading* and an f value of unity (100-percent diesels). These factors combine to yield the minimum value of (DR) proj, the highest computed value of Damb, and hence the greatest odor effect. For the highest value in the data base characterizing the generalized street canyon profile (St. Louis, San Jose, and Nashville), this approach yielded a dilution ratio of 190 and a value of Damb = 2.6. For the Manhattan receptor at East 45th Street, use of the highest one-hour CO average in calendar years 1972 and 1973 yielded a dilution ratio of 140 and a value of Damb = 3.0. At this odor level, the following response was reported from test subjects (Ref. 4-8).

Unpleasant or worse	72.9%
Very unpleasant or worse	17.0%
Unbearable	1.3%

In summary, these results indicate that, on an average basis, street canyon odor due to dieselization will not be a problem. However, localized, high-level exhaust concentrations may occur, producing odor effects generally regarded as unpleasant or worse.

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*Street level, San Jose data base

4.2.3 Parking Garage

4.2.3.1 Particulate Concentrations

The reader may refer to Section 3.4 for an overview of the calculation procedures and nomenclature used in the parking garage analysis. All vehicle fleet statistics in this analysis are based on the Manhattan passenger car fleet, as represented by the LDV diesel fractions and composite emission factors given in Table 3-2.

Table 4-11 shows the fraction of in-use passenger cars that are dieselized and the garage particulate emission rate $[fG_d + (1-f)G_g]$ as defined in Section 3.4. Table 4-11 also lists the combined (gasoline plus diesel) particulate emission rates for the idle and drive modes.

The first analysis case is that of unrestrained vehicle movement during off-peak periods; i.e., no queuing of vehicles trying to exit the garage. Table 4-12 presents the results (concentration above ambient) for the 25-percent dieselization case in the year 1990, where LDVD particulate emissions peak. These data are plotted in Figure 4-49. The particulate concentration at a given time is directly proportional to Y, the fraction of the garage capacity that is active. As noted in Section 3.4, Y = 1.5 percent is considered to be an approximate upper level for off-peak vehicle turnover in a very busy garage, while Y = 0.75 percent is considered to be an approximate upper level for many other garage situations. For a specific ventilation rate (q/V) of 0.067 min^{-1} (corresponding to the Uniform Building Code, Ref. 4-10), which is followed by many municipalities, a Y-value of 1.5 percent adds an equilibrium particulate concentration of about 48 $\mu g/m^3$ to the garage air. At the same ventilation rate, a Y-value of 0.75 percent produces an equilibrium particulate concentration addition of approximately 24 $\mu g/m^3$.

The New York City Building Code requires a minimum ventilation rate of 1 CFM per ft^2 of total garage floor area (Ref. 4-11). For a typical garage height of 10 ft, this yields a specific ventilation rate of 0.1 min^{-1}. This ventilation rate yields lower equilibrium particulate contributions of about 32 and 16 $\mu g/m^3$ for the two levels of vehicle activity, respectively.

Table 4-11. Exhaust Particulate Emission Rates, Parking Garage

Dieselization Rate	Year	Diesel Fraction f	$\left[fG_d+(1-f)G_g\right]$ μg/min	G_{idle} μg/min	G_{drive} μg/min
BC	1975	0.0011	112,170	46,160	134,180
	1985	0.0092	11,030	4,600	13,170
	1990	0.0099	6,380	2,840	7,560
	2000	0.0099	5,790	2,650	6,830
10%	1985	0.0505	14,950	6,660	17,720
	1990	0.0892	11,180	6,730	12,660
	2000	0.0999	10,390	6,960	11,530
25%	1985	0.1242	21,480	10,140	25,260
	1990	0.2226	18,110	12,790	19,890
	2000	0.2493	17,890	14,100	19,160

Table 4-12. Parking Garage Exhaust Particulate Concentrations -- Off-Peak Conditions (25-Percent Dieselization Rate, 1990)

$\mu g/m^3$ Above Ambient

Y^a	q/V^b Min^{-1}	t - Time from Start of Vehicle Activity, Minutes							
		1	2	5	10	15	30	60	
0.75%	.05	1.59	3.10	7.21	12.8	17.2	25.3	31.0	32.6
	.067	1.58	3.05	6.92	11.9	15.4	21.1	23.9	24.3
	.08	1.57	3.01	6.72	11.2	14.2	18.5	20.2	20.4
	.01	1.55	2.95	6.41	10.3	12.7	15.5	16.3	16.3
	.13	1.53	2.87	5.99	9.12	10.8	12.3	12.5	12.5
1.5%	.05	3.18	6.20	14.4	25.7	34.4	50.6	62.0	65.2
	.067	3.15	6.10	13.8	23.8	30.8	42.1	47.8	48.7
	.08	3.13	6.02	13.4	22.4	28.5	37.1	40.4	40.7
	.01	3.10	5.91	12.8	20.6	25.3	31.0	32.5	32.6
	.13	3.06	5.74	12.0	18.2	21.5	24.6	25.1	25.1

[a]Average number of active vehicles expressed as a percentage of garage parking capacity.

[b]Specific ventilation rate.

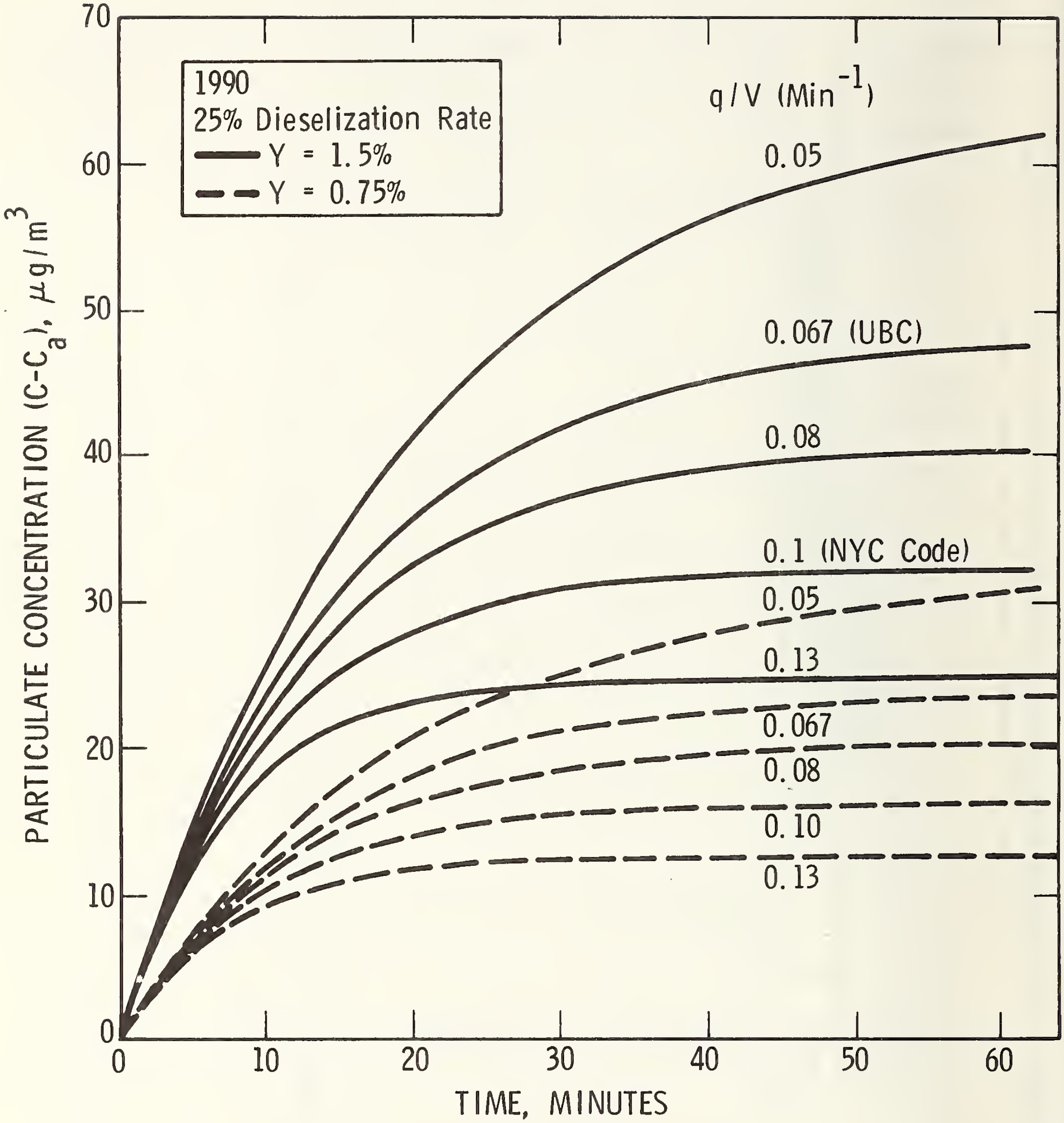

Figure 4-49. Parking Garage Exhaust Particulate Concentrations -- Influence of Ventilation Rate and Vehicle Activity Level

Table 4-13 shows the equilibrium particulate contribution as a function of projection year for the different dieselization rates. The analysis conditions here are Y = 1.5 percent and specific ventilation rate = 0.067 min^{-1}. Data for total exhaust particulates (gasoline plus diesel) and for diesel particulates only are provided. The data are plotted as a function of projection year in Figure 4-50. The high particulate concentration shown for the base case in 1975 is almost entirely due to the emissions of gasoline cars burning leaded fuel. This source decreases rapidly with the increased use of unleaded gasoline in catalyst-equipped cars.

As an example of saturation effects which may result from a large number of cars trying to leave the garage within a short time period, consider that a number of vehicles equal on the average to 25 percent of the garage parking capacity (Y = 25 percent) are idling in the garage over a period of 15 minutes. The resulting concentration profile is shown in Figure 4-51, which assumes that the overload conditions are suddenly superimposed on the off-peak conditions (Y = 1.5 percent) which were described in Figure 4-49. It is seen that the 15-minute overload period results in particulate concentrations above ambient of about 450 $\mu g/m^3$ and 360 $\mu g/m^3$ for specific ventilation rates of 0.067 min^{-1} and 0.1 min^{-1}, respectively. Figure 4-51 also shows the concentration decay following the peak, assuming no garage activity after the 15-minute overload condition.

It should be recalled that all the above numerical results are based on the simplifying assumption of complete mixing of the garage air with the vehicular exhaust. Local concentrations at specific sites within the garage may be greater or less than those shown, depending on the extent to which the actual mixing pattern departs from the assumed conditions. The shaded area in Figure 4-51 indicates a possible range of concentrations which might occur if the effective q/V varied locally down to 75 percent of the Uniform Building Code level (0.067). The actual variation in specific ventilation, however, is not known.

Another case considered is that of an enclosed garage with no mechanical ventilation. Such an arrangement is permissible under certain

Table 4-13. Equilibrium Exhaust Particulate Concentrations in Parking Garage, Off-Peak Conditions

$Y = 1.5\%$, $q/V = 0.067\ Min^{-1}$

Dieselization Rate	Year	Equilibrium Concentration, $\mu g/m^3$	
		Total Exhaust Particulates[a]	Diesel Exhaust Particulates
BC	1975	301.0	0.35
	1985	29.6	3.07
	1990	17.1	2.16
	2000	15.6	1.75
10%	1985	40.2	14.7
	1990	30.0	16.2
	2000	27.9	15.8
25%	1985	57.7	32.7
	1990	48.7	34.7
	2000	48.1	33.4

[a]LDVG, LDVD

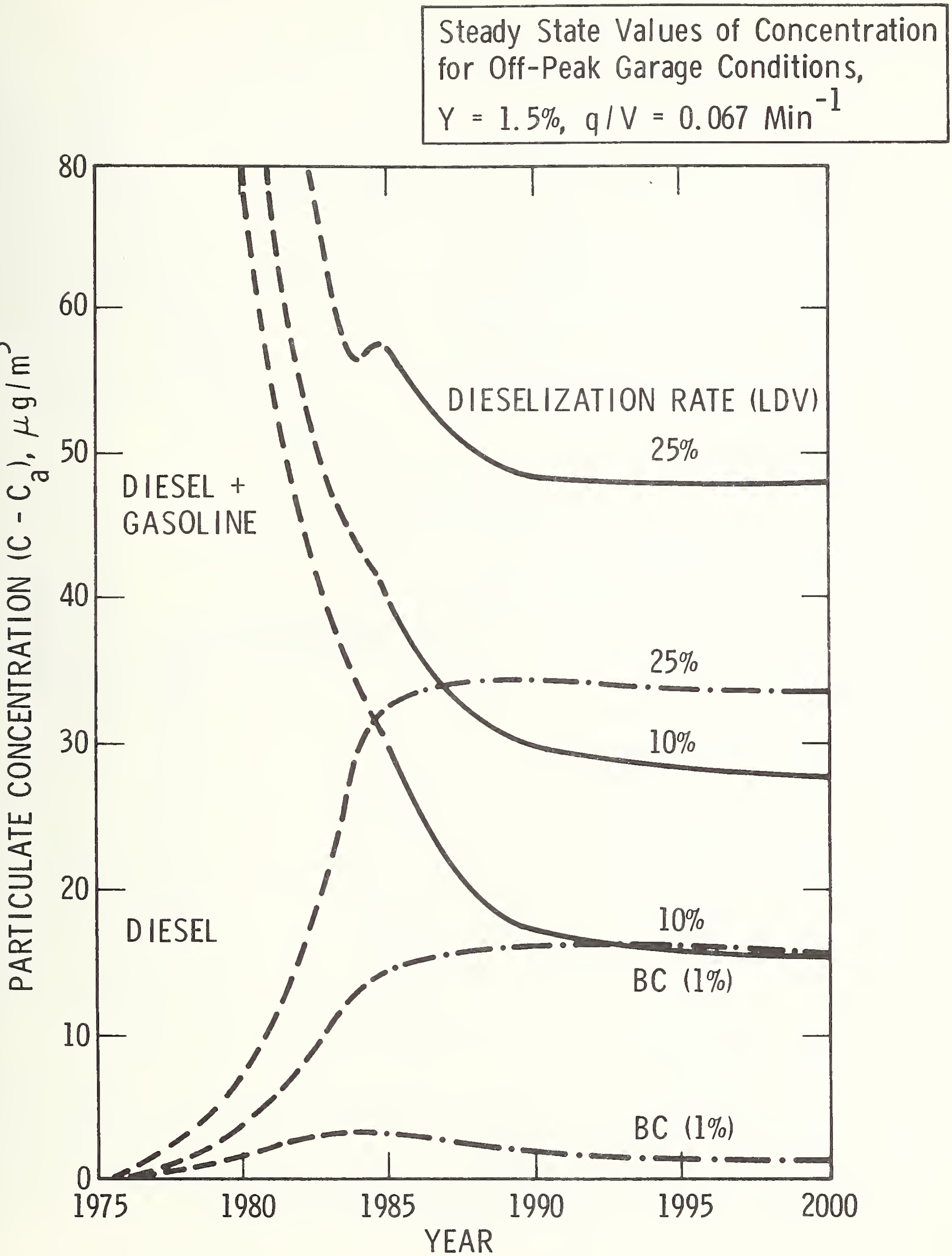

Figure 4-50. Garage Particulate Concentrations as a Function of Projection Year and LDV Dieselization Rate

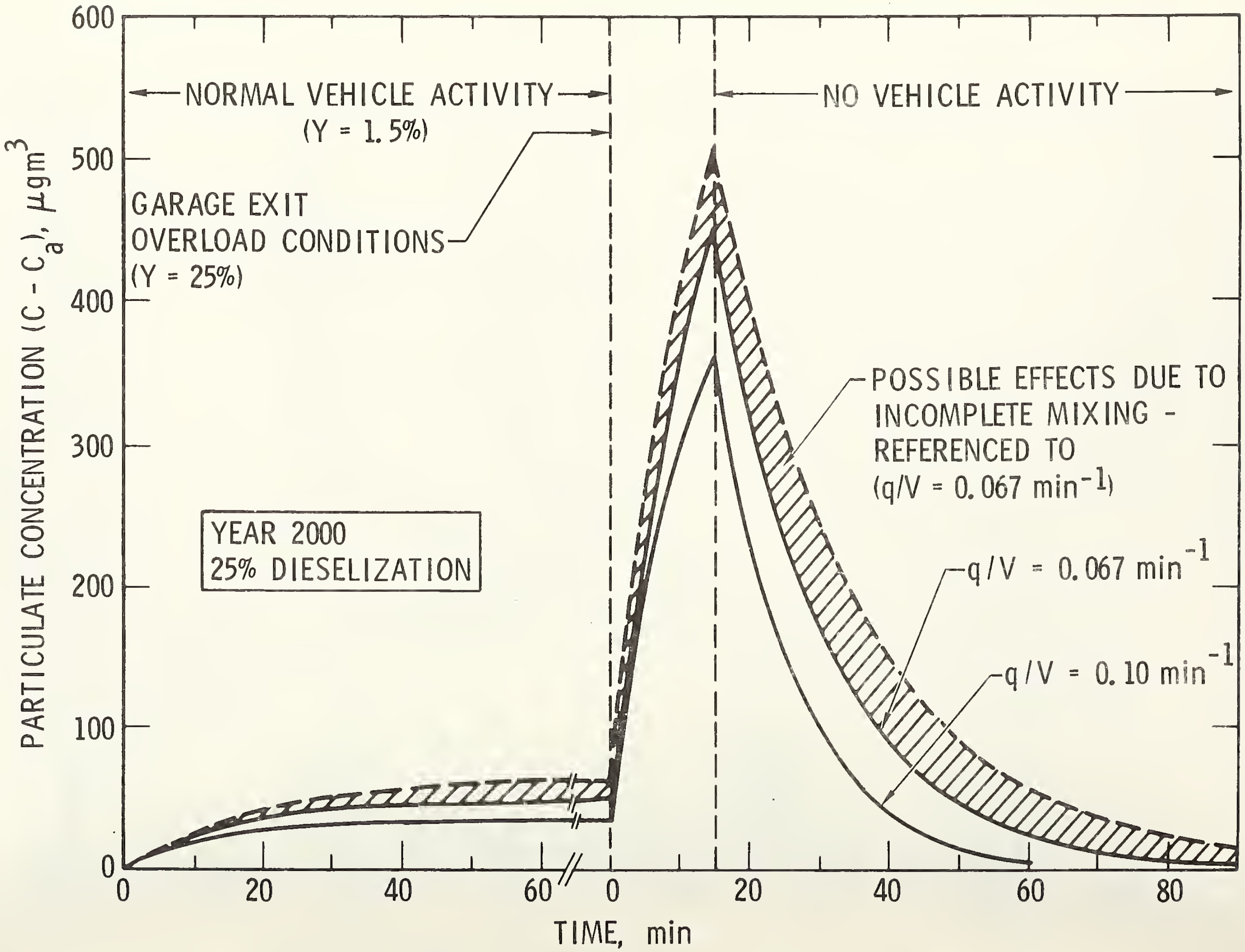

Figure 4-51. Garage Particulate Concentrations at Exit Overload Conditions

conditions in virtually all municipalities, including New York City. Under the Uniform Building Code, for example, no mechanical ventilation is required for a multi-story garage, provided that two or more sides of the enclosure have at least 50-percent open area. Under most micrometeorological conditions, such structures should provide adequate natural ventilation. This analysis considers the worst-case condition of complete calm, in which the only air circulation within the garage results from the vehicle exhaust flow itself and the turbulence generated by moving vehicles. A first approximation of these effects may be obtained by the use of Equation (1) of Section 3.4 with the substitution of a very small value of q/V. Taking the initial concentration in the garage to be equal to ambient ($C_o = C_a$), it may be shown that, for very small values of q/V, Equation (1) reduces to

$$(C - C_a) = \frac{N}{q}\left(\frac{qt}{V}\right)\left[fG_d + (1-f)G_g\right]$$

Expressed in terms of the vehicle activity factor Y and for $N_{cap}/V = 0.012$ (see Section 3.4), this may be written as

$$(C - C_a) = 0.012\ Yt\left[fG_d + (1-f)G_g\right]$$

Garage-average concentration effects under these worst-case conditions are summarized in Table 4-14. It is seen that high particulate concentrations result for time periods of about 30 minutes or longer, especially for the higher level of garage activity (Y = 1.5 percent).

It may be unlikely that a truly complete calm could exist throughout the garage for time periods as long as 30 minutes. The micrometerorology of the garage probably will be governed by the irregular shapes and consequent uneven thermal effects associated with the surrounding walls and buildings. This should produce some additional crossventilation of the

Table 4-14. Exhaust Particulate Concentrations in a Naturally Ventilated Enclosed Garage -- No Air Movement (25-Percent Dieselization, 1990)

$(C - C_a)$, $\mu g/m^3$		
t, min	Y = 0.75%	Y = 1.5%
1	1.6	3.3
10	16	33
30	49	98
60	98	196

garage interior. It may be shown that a local wind speed of 0.5 mph through the open wall area of the garage would yield an effective ventilation rate q/V of approximately 0.1 min^{-1}, roughly equivalent to the New York City building code requirement. Thus, although local regions within an unventilated garage may attain high particulate concentrations during calm periods, it appears that very high garage-average concentrations over long periods of time are a highly unusual occurrence.

4.2.3.2 Odor Effects

A discussion of the methodology for estimating odor effects was given in Section 3.1.2. For each analysis case shown in Table 4-13, the dilution ration DR as referenced to particulate concentrations in the garage is given by

$$DR = \frac{1}{f} \times \frac{\text{Particulate Concentration, Exhaust}}{\text{Particulate Concentration, Garage Atmosphere}}$$

The numerator in this relation calls for the combined exhaust concentration effect produced by active gasoline and diesel vehicles in the garage. This is given by

$$\frac{\left[G_g \cdot (1-f)\right]+\left[G_d \cdot f\right]}{\left[v_g \cdot (1-f)\right]+\left[v_d \cdot f\right]}$$

where the v's are the exhaust flowrates from gasoline and diesel cars and the other terms are as previously defined in Section 3.4.

The odor effect accompanying a given dilution ratio is expressed as

$$\text{Damb} = \text{dmode} + \frac{2 - \log \text{DR}}{\log 2}$$

To estimate Dmode, it was considered that "cold start," "idle," and "idle-acceleration" (Ref. 4-8) would be the predominant modes for garage operation, and on this basis a representative Dmode value of 3.5 was adopted for use.

Table 4-15 presents the odor effects data computed from the above relations. It will be noted that for the entire range of diesel fractions (f) that correspond to the dieselization scenarios studied, the calculated dilution ratios are so high as to preclude any noticeable odor effects. Recognizing, however, that in a random occurrence a very high fraction of diesel vehicles may be active, dilution ratios and odor effects for f values of 1.0 (100-percent diesels) were also determined and are included in the table. For this case, the calculated dilution ratios range from about 440 to 330, and the corresponding values of Damb range from 1.4 to 1.8. Taking the worst-case value to be on the order of 2, the lowest D-number treated, this condition would be graded as "unpleasant" or worse by 56 percent of the people exposed (Ref. 4-8). It may be noted that this worst-case effect bears little relationship to the assumed rates of LDV dieselization, except to the extent that a larger fraction of diesel vehicles in the fleet would increase the probability of a high diesel fraction occurrence.

Table 4-15. Garage Odor Effects

Garage Activity Mode	Dieselization Rate	Year	Diesel Fraction (f)	Dilution Ratio (DR)	Damb	DR f = 1.0	Damb f = 1.0
Off-Peak Vehicle Turn-Over	BC	1975	0.0011	403,000	(a)	443	1.4
		1985	0.0092	47,600	--	438	1.4
		1990	0.0099	44,300	--	439	1.4
		2000	0.0099	44,000	--	436	1.4
	10%	1985	0.0505	8,220	--	415	1.4
Y = 1.5%		1990	0.0892	4,440	--	396	1.5
$\frac{q}{V} = 0.067$ Min^{-1}		2000	0.0999	3,910	--	391	1.5
	25%	1985	0.1242	3,060	--	380	1.6
		1990	0.2226	1,530	--	441	1.7
		2000	0.2493	1,330	--	332	1.8
Overload Y = 25% $\frac{q}{V} = 0.067$ Min^{-1}	25%	2000	0.2493	269	2.1	67	4.1

[a]Negative values (no detectable odor)

The overload conditions depicted in Figure 4-51 result in higher computed Damb numbers of 4.1 and 3.8 for q/V of 0.067 min^{-1} and 0.1 min^{-1}, respectively. Odor levels of this intensity were stated to be rated as "unpleasant" or worse by about 80 percent of a test population, and "unbearable" by about 6 or 7 percent of the same test population (Ref. 4-8).

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5. ASSESSMENT OF ENVIRONMENTAL IMPACTS

5.1 AREAWIDE EFFECTS

In this section of the report, an assessment is made of the impacts on the environment indicated by the results of the regional area pollutant dump calculations in Section 4. The method of approach is to determine the percentage change in the areawide dump for each pollutant specie, and, assuming that the specie concentration changes proportionally with the mass dump, to draw conclusions as to the effects of dieselization on areawide air quality for the region in question.

This approach is an extension of the EPA linear rollback technique, which admittedly suffers from the assumption that the projected dump will be deposited in the same air volume as the base case or reference dump, rather than in an air volume with extended boundaries which would more realistically reflect typical patterns of regional growth. Accordingly, the technique yields results that tend to be conservatively high where the mass dump of the pollutant specie is projected to increase with regional area growth, and conservatively low where the pollutant dump is projected to decrease with regional area growth (through emission control measures or decentralization). Nevertheless, the method as applied here in a modified form is useful in indicating directional trends and order of magnitude estimates of air quality changes.

In the following paragraphs, the terms LDV dieselization and LDV's will be used as a convenient short form to denote vehicles in both the LDV class and the LDT class.

5.1.1 Particulates

For ease of reference, the curves in Section 4 showing the total (mobile plus stationary) pollutant dump for Manhattan, St. Louis, and Phoenix are reproduced here as Figures 5-1, 5-2 and 5-3, respectively. The particulate curves displayed in these figures represent the sum total of vehicle exhaust emission effects and particulate contributions from tire wear, fugitive dust, and stationary source stack emissions.

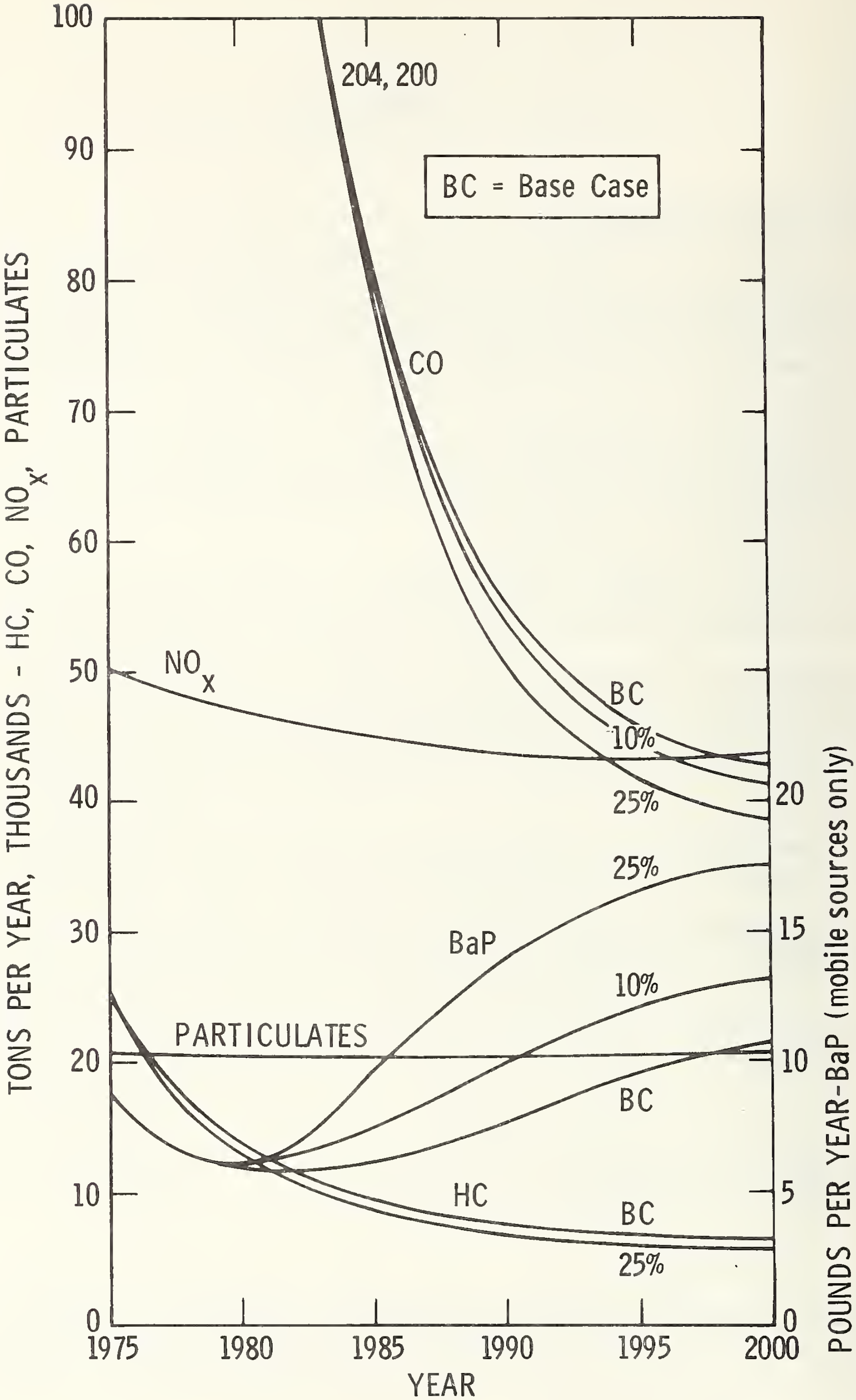

Figure 5-1. Manhattan Pollutant Dump -- Mobile Plus Stationary Source Contributions

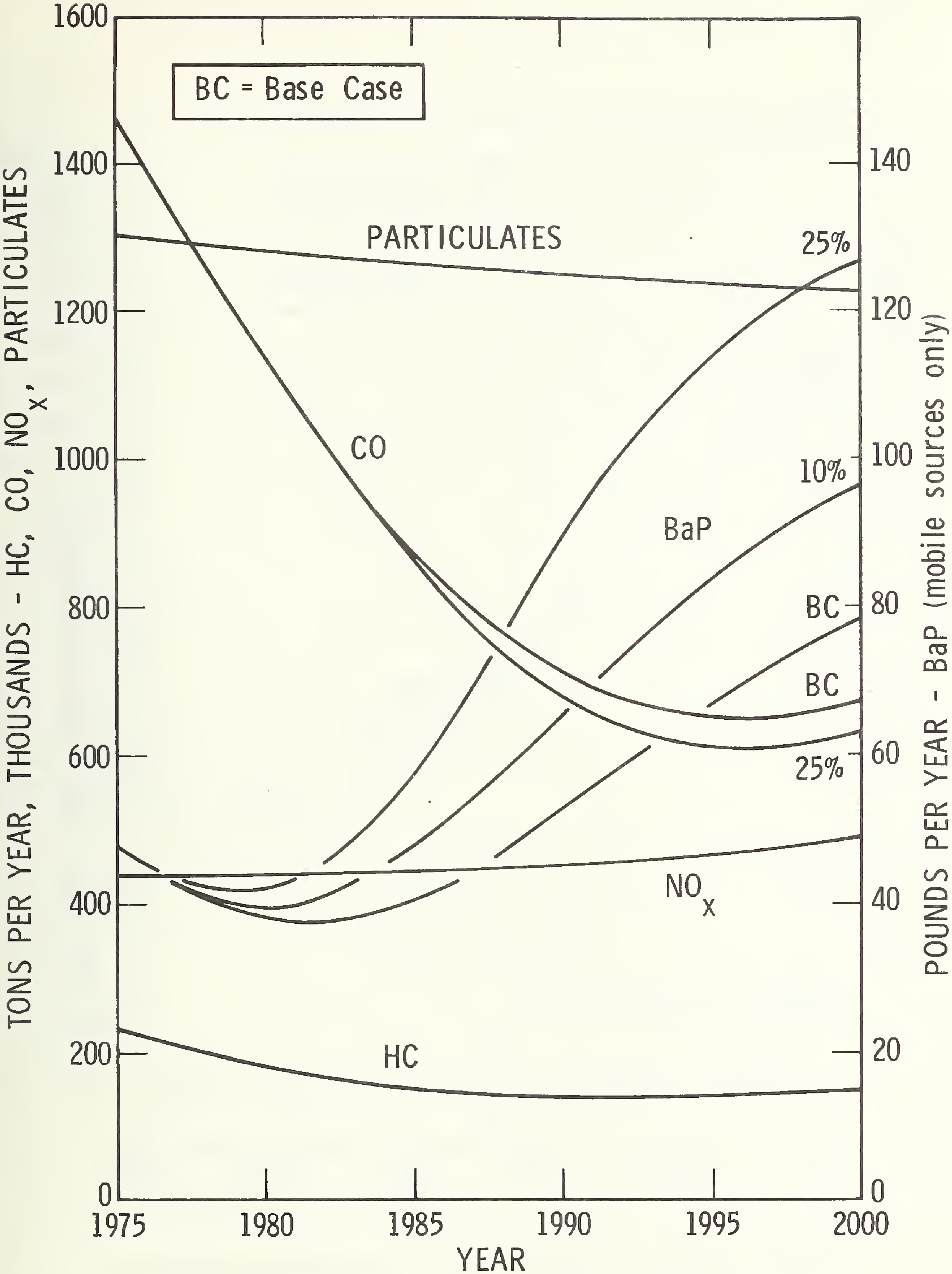

Figure 5-2. St. Louis Pollutant Dump -- Mobile Plus Stationary Source Contributions

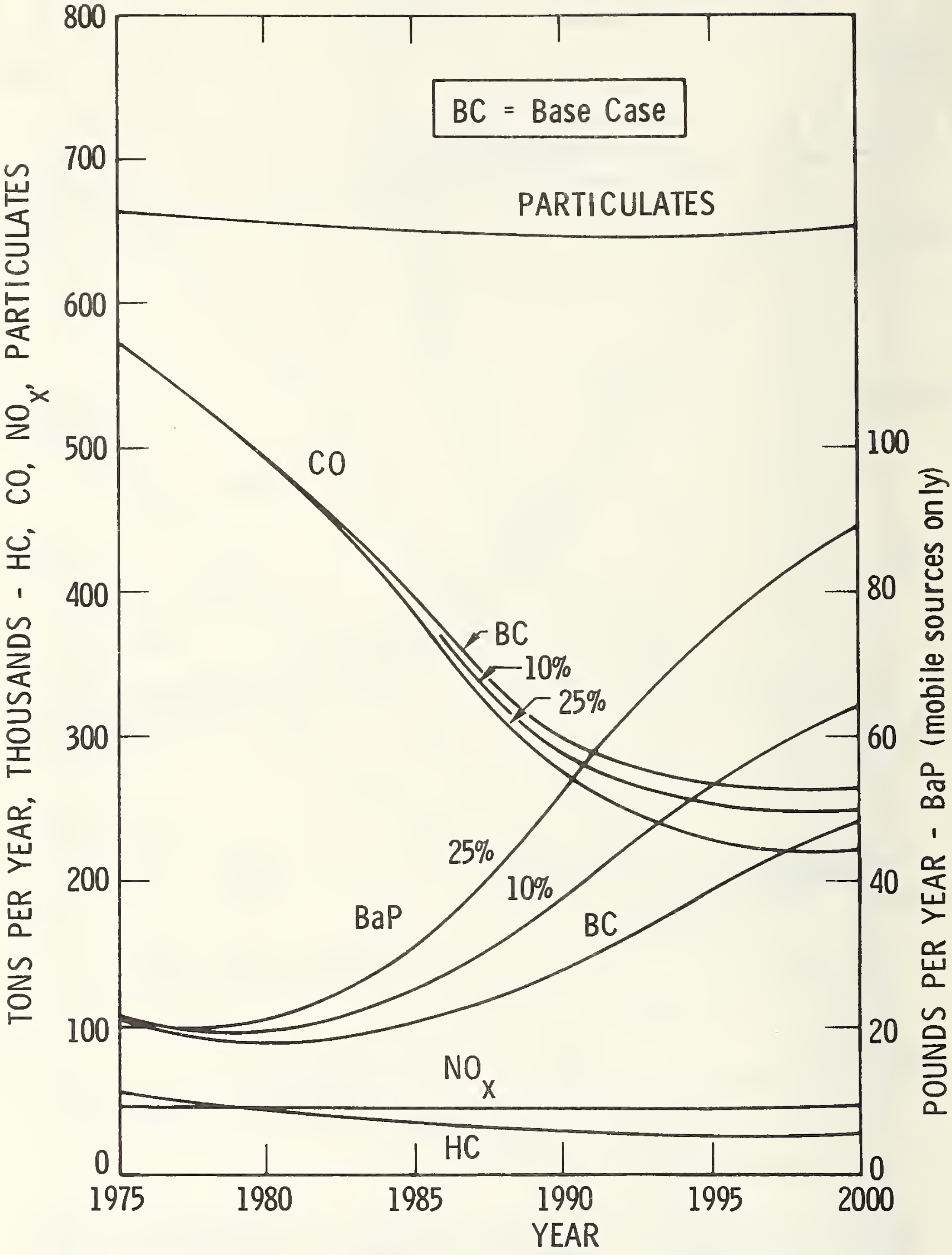

Figure 5-3. Phoenix Pollutant Dump -- Mobile Plus Stationary Source Contributions

For all regions, the particulate characteristic appears as a single-valued curve with a slightly decreasing trend relative to the 1975 base year and with no apparent influences due to LDV dieselization. The reason for this lack of visibility relative to LDV dieselization effects is that the mobile source particulate contribution is extremely small compared to the contribution from other sources. Taking Manhattan as an example, in the year 2000 at the maximum dieselization rate of 25 percent, the motor vehicle exhaust emission contribution is 597 tons per year. This compares to 451 tons/yr in the year 2000 base case, an increase of about 32 percent. Referenced to the total TSP dump of 20,597 tons/yr, however, the motor vehicle contribution is only 2.9 percent. The diesel contribution is 556 tons or 2.7 percent of the total. Considering combustion sources only (particulate sizes largely in the 0.1 to 1.0 μ range) the diesel contribution is 556 tons out of a total of 11,665 tons, or 4.8 percent. Comparable values for the base case in the year 2000 are 2.0 percent and 3.5 percent for the diesel contribution to TSP and the diesel contribution to the combustion source dump, respectively. Thus, the effect of LDV dieselization at the 25-percent rate is to add 0.7 percent to the total TSP dump and 1.3 percent to the particulate dump from combustion sources.

The Manhattan taxi scenario combines 100-percent dieselization of the Manhattan taxicab fleet with a 25-percent dieselization rate for Manhattan passenger cars. In the year 2000, the taxi dump is identical for both the adverse and optimistic assumptions for the fleet model year distribution (see Section 4.1.1.2), and would add 95 tons per year to the diesel dump for that year, or an additional 0.5 percent and 0.8 percent to the TSP and combustion source dumps, respectively. Relative to the base case in the year 2000, the Manhattan taxi scenario increases the Manhattan TSP dump by 1.2 percent.

The parameters quoted above for Manhattan are displayed for the three regional areas studied in Table 5-1. The changes made by LDV dieselization in all areas are quite small when compared to either the total particulate dump (T) or to the particulate dump from combustion sources (CS). The effects are largest for Manhattan where the 25-percent dieselization rate

Table 5-1. Areawide Particulate Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year				Percent Contribution				Percent Change From Base Case (BC)		
		Diesel (D)	Total Vehicle (TV)	Combustion Sources (CS)	Total Sources (T)	D/CS	D/T	TV/CS	TV/T	D	TV	T
Manhattan	BC	404	451	11,519	20,452	3.51	1.98	3.92	2.21	---	---	---
	10%	462	506	11,574	20,506	3.99	2.25	4.37	2.47	14.36	12.20	0.26
	25%	556	597	11,665	20,597	4.77	2.70	5.12	2.90	37.62	32.37	0.71
	25% PC + 100% Taxis	651	688	11,756	20,688	5.54	3.15	5.85	3.33	61.14	52.55	1.15
St. Louis	BC	2,964	3,290	70,304	1,221,638	4.22	0.24	4.68	0.27	---	---	---
	10%	3,357	3,667	70,681	1,222,015	4.75	0.27	5.19	0.30	13.26	11.46	0.03
	25%	4,006	4,288	71,302	1,222,637	5.62	0.33	6.01	0.35	35.16	30.33	0.08
Phoenix	BC	1,798	2,044	19,309	657,135	9.31	0.27	10.59	0.31	---	---	---
	10%	2,132	2,355	19,620	657,446	10.87	0.32	12.00	0.36	18.58	15.22	0.05
	25%	2,686	2,891	20,156	657,982	13.32	0.41	14.34	0.44	49.39	41.44	0.13

All values for year 2000

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

increases the total dump by about 0.7 percent. This larger influence results from the fact that mobile source emissions in this area constitute a larger fraction of the total particulate dump.

This study adopted an emission rate for LDV particulates of 0.25 g/mi beginning in 1985. If a value of 0.20 g/mi* had been used, then in the case of Manhattan the diesel particulate dump in the year 2000 would have been reduced from 556 tons/yr to 525 tons/yr, an increase relative to the base case of 30 percent. Compared to the TSP dump in the 25-percent case, the total motor vehicle and diesel dumps at the reduced diesel emission rate represent contributions of 2.7 percent and 2.5 percent, respectively.

The results in Table 5-1 may be summarized as follows. For the three regions examined, the effect of LDV dieselization at the 25-percent rate in the year 2000 is to cause an increase in the diesel vehicle particulate dump of from 35 to 49 percent. The diesel dumps at the 25-percent rate represent contributions to the regional area TSP dumps of from 0.3 percent to 2.7 percent. The TSP contributions are increased relative to the base case (1 percent LDV/0.2 percent LDT dieselization) by 0.71 percent in Manhattan, 0.08 percent in St. Louis, and 0.13 percent in Phoenix. Effects in this range might apply to all urban areas nationwide.

The effect of 100-percent dieselization of taxis combined with 25-percent dieselization of passenger cars in Manhattan is to cause a 61-percent increase in the Manhattan diesel dump. This (diesel total) dump represents a three-percent contribution to the area TSP dump, an increase over the base case of about one percent.

These results show that, if particulates are treated as a group-pollutant uniformly distributed over the regional area, the effects of dieselization would have a negligible effect on regional air quality. Local urban area conditions may have different ramifications, however, and these are discussed under local site effects.

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* Proposed as a standard in a recent EPA notice of rulemaking.

5.1.2 Benzo(a)pyrene

Diesel BaP emission rates were estimated at two levels, as discussed in Section 2. Dump quantities for both estimates and for all dieselization scenarios are presented in Appendix D. The dump profiles displayed in Figures 5-1, 5-2, and 5-3 are based on the high estimate only. It should be noted that these curves represent only the mobile source contribution to the areawide BaP dump. Data on stationary source BaP emissions* were not available for the regions examined, nor could they be estimated with reasonable certainty. The following discussion addresses the mobile source effects.

The BaP characteristics for all three regional areas show similar trends. The dump initially declines as catalyst-equipped vehicles with relatively low BaP emission rates enter the fleet and displace older, noncatalyst vehicles. The dump reaches a minimum in about 1980 and then increases as the fleet population of diesel vehicles grows in the later projection years. The profile for the base case shows a strong increasing trend, reflecting the growth projected for diesel vehicles in the HDV class. The outstanding feature of these curves is their marked sensitivity to LDV dieselization rate. This would be expected in view of the fact that diesel LDV's emit 10 to 60 times the amount of BaP as the catalyst-equipped gasoline vehicles they replace.

Table 5-2 provides a listing of the high and low estimates of BaP dump for the three metropolitan regions in the year 2000, considering both diesel-only and total vehicle emission sources. Also shown is the percent diesel contribution and the percent dump increase relative to base case conditions in the year 2000. Taking Manhattan at the maximum dieselization rate of 25 percent, for example, the BaP dump for total vehicle sources ranges from 3.5 to 18.0 lb/yr, an increase relative to the base case of from 40 to 68.2 percent. The dump largely consists of diesel emissions, as may be seen by comparing the total vehicle quantities to the diesel-only quantities. The

*Typical sources are coke ovens, residential wood-burning fireplaces, burning coal refuse piles, and coal-fired residential furnaces.

Table 5-2. Areawide BaP Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Pounds Per Year				Percent Diesel Contribution (D/TV)		Percent Change From Base Case (BC)			
		Diesel (D)		Total Vehicles (TV)				Diesel (D)		Total Vehicles (TV)	
		Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.	Low Est.	High Est.
Manhattan	BC	1.9	10.1	2.5	10.7	76.0	94.4	----	----	----	----
	10%	2.3	12.8	2.8	13.3	82.1	96.2	21.1	26.7	12.0	24.3
	25%	3.0	17.5	3.5	18.0	85.7	97.2	57.9	73.3	40.0	68.2
	25% PC + 100% Taxis	3.8	22.0	4.2	22.4	90.5	98.2	100.0	117.8	68.0	109.3
St. Louis	BC	13.8	73.8	18.2	78.2	75.8	94.4	----	----	----	----
	10%	17.0	92.6	21.1	96.7	80.6	95.8	23.2	25.5	15.9	23.7
	25%	22.1	123.5	25.7	127.1	86.0	97.2	60.1	67.3	41.2	62.5
Phoenix	BC	8.3	45.0	11.8	48.5	70.3	92.8	----	----	----	----
	10%	11.0	61.0	14.2	64.2	77.5	95.0	32.5	35.6	20.3	32.4
	25%	15.3	87.2	18.1	90.0	84.5	96.9	84.3	93.8	53.4	85.6

All values for year 2000

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

diesel contribution is 3.0 to 17.5 lb/yr, an increase relative to the base case (diesel-only) reference of from 57.9 to 73.3 percent. The effect of 100-percent taxi dieselization is to add from 0.7 to 4.4 lb/yr to the total vehicle dump for the 25-percent dieselization case. The total dump for the taxi scenario, then, represents an increase relative to the base case of from 68 to 109.3 percent.

In terms of percentage increase, the effects quoted above for Manhattan do not vary widely among the regions examined. Phoenix, with its high projected VMT growth, shows the highest range of increase in total vehicle BaP emissions (53.4 to 85.6 percent), excluding the Manhattan taxi scenario.

The results of Table 5-2 may be summarized as follows. For the three regions examined, the effect of LDV dieselization at the 25-percent rate is to cause an increase in the mobile source BaP dump of from 40 to 53 percent, based on a low estimate of diesel vehicle BaP emission rate, and from 63 to 86 percent based on a high estimate of diesel BaP emission rate. For Manhattan, the effect of 100-percent dieselization of taxis combined with 25-percent dieselization of passenger cars is to cause an increase in the mobile source BaP dump of from 68 to 109 percent relative to the year 2000 base case. Excluding the Manhattan taxi scenario, the relative increases in BaP level do not vary widely among the regions examined.

There is no direct method for evaluating the effect of BaP on the environment. BaP has typically been measured and used in emissions research and air pollution monitoring as a general indicator of the presence of polynuclear aromatic hydrocarbons, but its value as an accurate index of total PNA emissions from a given source is questionable. Lacking the stationary source emissions for BaP, it is not possible to evaluate the relative contribution of dieselization to the specie dump.

5.1.3 Hydrocarbons

For all regions examined, the HC characteristic exhibits a declining trend relative to the 1975 base year, due largely to improved HC control of gasoline-powered vehicles using catalyst devices. Though not visible in the plots for St. Louis and Phoenix because of the scales selected for plotting, the effect of dieselization is to reduce the HC dump in all three regional areas examined, an effect which may be expected to hold for all urban areas nationwide.

Two factors account for this result. One is that diesel vehicles have no evaporative HC emission losses. A second more significant effect is that, under the assumptions of this study, diesel vehicles suffer no loss in exhaust emission control with accumulated mileage, while gasoline vehicles are subject to significant deterioration effects with accumulated mileage. Thus, while new gasoline LDV's projected for the 1980+ time period initially emit exhaust HC at lower rates than their diesel vehicle counterparts, the effect of accumulated mileage produces emission levels that are significantly higher than those of diesel LDV's. Consequently, each replacement of a gasoline vehicle by a diesel vehicle represents an incremental reduction in the area dump over the vehicle lifetime.

The salutory effects of dieselization on HC can be seen in the Figure 5-1 plot for Manhattan and in Table 5-3, which provides a listing of the dump effects in the year 2000 for the three regional areas examined. Whereas the diesel HC dump and its contribution to total HC increases with dieselization rate, as would be expected from an increased number of diesel vehicles in the fleet, the total vehicle dump, along with the total dump from all sources, decreases. In the case of Manhattan at the 25-percent dieselization rate, for example, the diesel dump increases by 45 percent relative to the base case while the total vehicle dump decreases by 13.5 percent. These effects translate into a reduction in total HC emissions of 9.3 percent relative to the year 2000 Manhattan base case.

This trend occurs in all three regional areas; however, the magnitude of the effect varies somewhat. The largest improvement (9.3 percent) is indicated for Manhattan, where vehicle sources contribute a large fraction of the total regional HC dump (65 percent). The HC reduction for Phoenix is about 6 percent, while the improvement for St. Louis is about 3 percent.

Table 5-3. Areawide HC Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year			Percent Contribution		Percent Change from Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	579	4,299	6,251	9.3	68.8	---	---	---
	10%	677	4,086	6,038	11.2	67.7	16.9	-5.0	-3.4
	25%	839	3,718	5,670	14.8	65.6	44.9	-13.5	-9.3
St. Louis	BC	4,240	31,880	146,749	2.9	21.7	---	---	---
	10%	4,971	30,403	145,272	3.4	20.9	17.2	-4.6	-1.0
	25%	6,164	27,646	142,515	4.3	19.4	45.4	-13.3	-2.9
Phoenix	BC	2,577	28,986	74,089	3.5	39.1	---	---	---
	10%	3,238	27,202	72,305	4.5	37.6	25.6	-6.2	-2.4
	25%	4,302	24,479	69,582	6.2	35.2	66.9	-15.5	-6.1

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

While not explicitly accounted for in the emissions inventory, evaporative HC emissions due to fuel transfer losses should be mentioned here in the context of emission effects favorable to the diesel system. Refueling of gasoline vehicles at service stations and the operations associated with gasoline distribution result in HC emissions (raw gasoline vapor) to the atmosphere. The major sources of these emissions are displacement of vapor from vehicle fuel tanks during refueling, from underground storage tanks during filling, from tank truck loading at bulk terminals, and from spill losses.

Uncontrolled emissions of HC from these sources can be shown to be comparable to vehicle exhaust emissions. For example, the total hydrocarbon emission per service station dispensing 300,000 gal annually is estimated to be roughly 7000 to 9000 lb (including associated bulk terminal losses.) Taking a midrange value of 8000 lb and assuming a fleet average (LDV and LDT) fuel economy of, say, 28 mpg for the year 2000, then the 8000 lb/yr figure is equivalent to a vehicle emission rate of 0.43 g/mi.

Characteristically, HC emissions from fuel marketing operations vary roughly in proportion to the vapor pressure of the fuel. In contrast to gasoline, diesel fuel has an extremely low vapor pressure (on the order of 1/200 that of gasoline), so that HC emissions from diesel fuel marketing operations can be expected to be extremely low. This feature of the diesel system, then, would translate into a further reduction in the areawide HC dump associated with LDV dieselization, if gasoline fuel transfer losses were to remain uncontrolled. For example, in the year 2000 at the 25-percent dieselization rate, the reduction in HC dump would be about 280 tons/yr for Manhattan, 1860 tons/yr for St. Louis and 1580 tons/yr for Phoenix. As a percentage of total dump, these values are equivalent to areawide HC emission reductions of 4.9 percent, 1.3 percent, and 2.3 percent, respectively.

It must be noted that fuel transfer emission control measures in the form of vapor recovery systems variously applicable to storage tanks, tank trucks and bulk loading stations, as well as vehicle refueling operations, have been and are being implemented. High vapor recovery efficiencies are reported for these systems, so that only a small fraction of the HC reductions quoted above could reasonably be designated as a dieselization-related advantage in the later projection years.

The areawide results for HC may be summarized as follows. The effect of LDV dieselization is to decrease the HC dump. For the three regions examined, dieselization at the 25-percent level decreases the total vehicle contribution by from 13.3 to 15.5 percent and decreases the regional area total dump by 9.3 percent for Manhattan, 3 percent for St. Louis, and 6 percent for Phoenix. This general trend is expected to hold for all urban regions nationwide, with the greatest improvements to be seen for those regions where motor vehicle emissions represent a large fraction of the total HC dump. An additional effect of dieselization is to reduce HC emissions associated with gasoline marketing operations, but the magnitude of the reduction is expected to become small as vapor recovery control measures are introduced nationwide.

These results indicate that the HC quality of the urban atmosphere will improve slightly with LDV dieselization. It must be noted, however, that the magnitude of the improvement that will be realized in fact is contingent upon the degree to which future diesel and gasoline vehicles match the emission levels and deterioration characteristics adopted as a base for this study.

5.1.4 Carbon Monoxide

For all regions examined, the CO characteristic shows a marked decline in level relative to the 1975 base year, a characteristic that is largely due to improved CO control of the gasoline component of the LDV fleet using catalytic control devices. The effect of LDV dieselization is to further reduce the CO dump in the three regions examined. This trend is expected to hold nationwide.

The reduction in CO dump due to dieselization comes about as a result of the fact that diesel LDV's are projected to have a lower lifetime-average CO emission rate than gasoline vehicles. Whereas at low mileage slightly higher rates are indicated for diesels compared with gasoline vehicles (see Tables 2-8 and 2-9), the effect of emission control deterioration with mileage accumulation in gasoline vehicles produces a higher average CO emission rate over the vehicle lifetime (CO deterioration in diesel vehicles is taken to be zero, in accordance with EPA guidelines).

The LDV dieselization effect on CO improvement is amplified in Table 5-4, which lists the pertinent dump parameters for the year 2000 for the three regions examined. It may be seen that, while the diesel dump increases with dieselization rate, the total vehicle dump decreases as diesel vehicles replace gasoline vehicles in the fleet, causing a net incremental reduction in vehicle-average CO emission rate. In Manhattan at the 25-percent dieselization rate, for example, the total vehicle source contribution (representing 77.3 percent of the total CO dump) decreases by 16.1 percent, resulting in a decrease in the areawide total CO dump of 12.9 percent. The effects vary among the three areas examined, with Phoenix showing the greatest sensitivity to change (-16.7 percent) because of its high vehicle-to-total source fraction (90 percent).

In summary, the areawide effect of LDV dieselization on CO is to decrease the total vehicle and therefore the total source pollutant dump. The reduction in total dump is substantial for all three regional areas examined: 12.9 percent for Manhattan, 6.6 percent for St. Louis, and 16.7 percent for Phoenix. While this trend is expected to hold for all urban areas nationwide, the magnitude of the reduction will vary with the relative importance of vehicle source contributions in each regional area. For areas such as Phoenix, with a relatively small industrial base, the effects will be substantial. For large industrial centers such as St. Louis, with a heavy CO contribution from industrial process sources, the effects will be smaller, though significant. As a corollary observation, it may be noted that in an area with a substantial CO problem, a small percentage reduction in the CO dump could have a significant impact on the areawide-average pollutant concentration level. On the other hand, in an area where CO is not a general problem, a large percentage reduction in CO dump may have little impact on or relevance to an already low CO concentration level.

Table 5-4. Areawide CO Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year			Percent Contributions		Percent Change From Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	1,116	4,692	43,373	2.6	10.8	---	---	---
	10%	1,350	4,619	43,300	3.1	10.7	21.0	-1.6	-0.2
	25%	1,737	4,484	43,165	4.0	10.4	55.6	-4.4	-0.5
St. Louis	BC	8,171	34,784	490,778	1.7	7.1	---	---	---
	10%	9,830	34,093	490,087	2.0	7.0	20.3	-2.0	-0.1
	25%	12,551	33,012	489,006	2.6	6.8	53.6	-5.1	-0.4
Phoenix	BC	5,042	29,895	48,717	10.3	61.4	---	---	---
	10%	6,489	29,230	48,052	13.5	60.8	28.7	-2.2	-1.4
	25%	8,864	27,919	46,741	19.0	59.7	75.8	-6.6	-4.1

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

These results indicate that, on an areawide basis, the CO quality of the urban atmosphere will improve with LDV dieselization. As in the case of HC, the magnitude of the improvement that is actually realized will depend on the degree to which future diesel and gasoline vehicles match the emission levels and deterioration characteristics adopted for use in this study.

5.1.5 Oxides of Nitrogen

In Figures 5-1, 5-2, and 5-3 the NO_x characteristic appears as a single valued curve which, with reference to the 1975 base year level, descends with projection year in the case of Manhattan, ascends with projection year in the case of St. Louis, and follows a generally level path with projection year in the case of Phoenix. These varying trends reflect differences in the regional projections for growth in stationary source emissions in combination with the influence of a general decrease in vehicle emissions due to improved NO_x control measures. For Manhattan, the stationary source emission growth is zero; consequently, the total NO_x dump declines with projection year, reflecting the trend of vehicle source emissions in a regional area where VMT is constant over the time period of interest.

For all three regions, the effect of LDV dieselization is to reduce the NO_x dump relative to the base case. This occurs because the lifetime-average NO_x rate for diesel LDV's is lower than that for gasoline LDV's. The higher gasoline rate is a result of projected emission deterioration effects. Thus, each replacement of a gasoline vehicle by a diesel vehicle produces an incremental reduction in the regional area NO_x dump over the vehicle lifetime. For this reason, the reduction in NO_x due to dieselization is expected to apply to all urban areas nationwide.

This trend is not visible in the NO_x plot profiles because the reductions are small or the vehicle contribution to total NO_x emissions is small, or both influences apply in the respective regional areas. The effects are apparent, however, in Table 5-5, where the parameters of dump for the year 2000 are listed. For Manhattan at the 25-percent dieselization rate, the total vehicle NO_x dump is 4484 tons, a reduction relative to the base case of

Table 5-5. Areawide NO_x Effects, Year 2000

Regional Area	Dieselization Rate	Dump, Tons Per Year			Percent Contributions		Percent Change From Base Case (BC)		
		Diesel (D)	Total Vehicles (TV)	Total Sources (T)	D/T	TV/T	D	TV	T
Manhattan	BC	1,116	4,692	43,373	2.6	10.8	---	---	---
	10%	1,350	4,619	43,300	3.1	10.7	21.0	-1.6	-0.2
	25%	1,737	4,484	43,165	4.0	10.4	55.6	-4.4	-0.5
St. Louis	BC	8,171	34,784	490,778	1.7	7.1	---	---	---
	10%	9,830	34,093	490,087	2.0	7.0	20.3	-2.0	-0.1
	25%	12,551	33,012	489,006	2.6	6.8	53.6	-5.1	-0.4
Phoenix	BC	5,042	29,895	48,717	10.3	61.4	---	---	---
	10%	6,489	29,230	48,052	13.5	60.8	28.7	-2.2	-1.4
	25%	8,864	27,919	46,741	19.0	59.7	75.8	-6.6	-4.1

All values for year 2000

BC = Base case (1% LDV/0.2% LDT dieselization)

4.4 percent. The vehicle contribution to the total area dump is 10.9 percent. These factors in combination produce a reduction in the total NO_x dump of 0.5 percent.

The magnitude of the NO_x dump reduction varies among the regions examined. The effect is greatest for Phoenix, where the motor vehicle contribution to the total pollutant dump is large (about 60 percent). Here the reduction of areawide NO_x emissions due to dieselization at the 25-percent rate is 4.1 percent.

To summarize, the effect of LDV dieselization on NO_x is to produce a small decrease in the total pollutant dump in each of the regions examined. At the 25-percent dieselization rate, the decrease in dump is 0.5 percent for Manhattan, 0.4 percent for St. Louis, and 4.1 percent for Phoenix. This trend is expected to hold for all urban areas nationwide. The improvement will be greatest in those areas where motor vehicles represent an important source of areawide NO_x emissions.

These results indicate that the NO_x quality of the urban atmosphere will improve slightly with LDV dieselization. Since the effect is small, minor deviations from the assumed conditions for gasoline and diesel vehicle emission levels and deterioration effects could negate, enhance, or reverse the trend indicated.

5.2 LOCAL SITE EFFECTS

Exhaust pollutant concentration effects in local urban traffic sites were characterized in Section 4. These effects are examined here with regard to impacts on the local environment.

5.2.1 Particulates

5.2.1.1 Urban Freeway and Urban Street Canyon

The impact assessment for particulates in the urban freeway and urban street canyon parallels the assessment made for areawide effects in that it is based, in part, on conditions that would result if the sites examined were to be situated within each of the metropolitan regions studied. The method of approach is to establish representative values for the ambient levels of particulate concentration in these regions, and, using these as a base, to compute the absolute concentrations which would exist in each site for various dieselization scenarios. Effects are projected to the year 2000. These results are compared with the Federal ambient air quality standard for TSP. Trends relative to the baseline case are assessed, and the significance of the concentration contribution due to LDV dieselization is evaluated.

The assessment uses the annual geometric mean concentration as a reference for evaluating air quality effects, since the maximum annual 24-hour concentration was either not reported or not given in a usable form for the regional areas studied. It may be seen, however, that many of the parameters used as a gauge of air quality impact (e.g., percent diesel concentration contribution) would remain the same if annual geometric mean concentrations were converted to 24-hour maximum concentrations using a typical 3 to 1 constant conversion factor.

Local site results were presented in Section 4 in terms of exhaust particulate concentrations above ambient. The term ambient is used here to denote the particulate concentration contribution from all sources other than motor vehicle exhaust emissions. Absolute or actual concentrations in a given site, then, are computed as the sum of the motor vehicle exhaust contribution and the ambient concentration.

Average ambient concentration levels for Manhattan, St. Louis, and Phoenix were determined from TSP measurements data (annual geometric means) supplied by the regional air pollution control agencies. The measured data in each region were reduced to a single representative value for the 1975 base year. Each regional-representative value was converted to an ambient quantity by removing the areawide motor vehicle exhaust contribution.* Ambient concentrations for the year 2000 were scaled in proportion to the areawide, non-vehicle-exhaust particulate dumps.

These quantities are displayed in Table 5-6. Very high ambient levels relative to the Federal standard may be noted. In the case of St. Louis and Phoenix, fugitive dust contributions overwhelm all other sources,

*This measure avoided double-counting motor vehicle exhaust emission effects.

Table 5-6. Regional Area TSP Concentrations, Annual Geometric Means, $\mu g/m^3$

Federal Primary Air Quality Standard = $75 \mu g/m^3$

Regional Area	1975 Base Year		Year 2000
	Measured	Ambient[a]	Ambient[b]
Manhattan	70	67	67
St. Louis	81	81	75
Phoenix	122	122	121

[a]Obtained from measured values by removing motor vehicle exhaust contribution.

[b]Scaled from 1975 ambient values in proportion to areawide nonexhaust particulate dump.

mask the adjustment from measured to ambient conditions, and are the major cause for the high ambient levels shown.

Annual geometric mean exhaust emission concentrations for the urban freeway were presented in Table 4-4 for a best-estimate case. These values, which were based on Manhattan fleet statistics, may be adjusted to any regional area by scaling the numbers in proportion to the regional particulate emission factors. Proceeding in this manner, and using the ambient concentration levels given in Table 5-6, absolute TSP concentration levels for the urban freeway were calculated for the three regional areas studied. These and other parameters pertinent to the environmental assessment are shown in Table 5-7 for all dieselization scenario conditions in the year 2000. Values are displayed for three roadway positions of possible concern with respect to human exposure: the median position, 100 ft from the roadway edge, and 300 ft from the roadway edge.

As a first observation it may be noted that the diesel dominates the vehicle exhaust concentration contribution throughout the table (it accounts for about 90 percent of the total); no further comment in this area need be made. The parameters of major interest in the table are the total suspended particulates quantity (T), the percent diesel contribution (D/T), and the percent change from baseline conditions for the diesel and total vehicle contributions. It may be seen that the TSP standard of 75 $\mu g/m^3$ is exceeded in every scenario case, including the base case, a result which is largely due to the very high ambient concentration levels in the three regions examined. As indicated in Table 5-6, the background concentrations are near, at, and over the standard for Manhattan, St. Louis, and Phoenix, respectively, with no contribution from vehicle exhaust emission sources included. This condition may be typical of many urban areas nationwide, so that dieselization at any level would tend to exacerbate the problem of achieving the air quality standard for TSP.

As an indicator of air quality effects, TSP by itself is perhaps an unsatisfactory gauge, since it fails to differentiate between suspended

Table 5-7. Urban Freeway Particulate Effects, Year 2000
(Annual Geometric Mean Concentrations)

Regional Area	Dieseliza-tion Rate	Median Position								100 Feet From Roadway Edge								300 Feet From Roadway Edge							
		Concentration, $\mu g/m^3$			%Contribution		% Change from BC			Concentration, $\mu g/m^3$			%Contribution		% Change from BC			Concentration, $\mu g/m^3$			%Contribution		% Change from BC		
		Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T
Manhattan	BC	24.1	26.9	94	26	29	--	--	---	12.3	13.7	81	15	17	--	--	---	8.0	9.0	76	11	12	--	--	---
(Ambient = 67 $\mu g/m^3$)	10%	27.6	30.1	97	28	31	14	12	3.4	14.1	15.4	82	17	19	14	12	2.1	9.2	10.1	77	12	13	14	12	1.4
	25%	33.2	35.4	102	32	35	38	32	9.0	16.9	18.1	85	20	22	38	32	5.4	11.0	11.8	79	14	15	38	32	3.7
	25% PC + 100% Taxis	38.6	40.9	108	36	38	61	53	15.0	19.7	20.8	88	22	24	61	53	8.8	12.9	13.6	81	16	17	61	53	6.0
St. Louis	BC	25.9	28.7	104	25	28	---	--	---	13.2	14.6	90	15	16	--	--	---	8.6	9.6	85	10	11	--	--	---
(Ambient = 75 $\mu g/m^3$)	10%	29.4	31.9	107	28	30	13	11	3.1	15.1	16.3	91	17	18	13	11	1.9	9.8	10.7	86	11	12	13	11	1.3
	25%	35.2	37.4	112	31	33	35	30	8.4	17.9	19.1	94	19	20	35	30	5.0	11.7	12.5	88	13	14	35	30	3.4
Phoenix	BC	19.0	21.5	142	13	15	--	--	---	9.7	10.9	132	7.4	8.3	--	--	---	6.3	7.2	128	4.9	5.6	--	--	---
(Ambient = 121 $\mu g/m^3$)	10%	22.6	24.7	146	16	17	19	15	2.2	11.6	12.6	134	8.7	9.4	19	15	1.3	7.5	8.3	129	5.8	6.4	19	15	0.8
	25%	28.1	30.3	151	19	20	49	41	6.2	14.3	15.5	136	10.5	11	49	41	3.5	9.3	10.1	131	7.1	7.7	49	41	2.3

All values for year 2000, Traffic rate = 188,000 veh/day

BC = Base Case (1% LDV/0.2% LDT dieselization)

PC = Passenger Cars

particles of a larger size range, which may be benign to human health, and those typical of diesel emissions which largely fall in the size range below 1μ and may be injurious to health by reason of their small size and possible carcinogenic effect. On this basis, the diesel concentration contribution may be a more useful parameter to investigate. Table 5-7 shows that the largest contribution occurs at the median position where values ranging from about 28 to 35 $\mu g/m^3$ are indicated at the 25-percent dieselization rate. These levels drop off with distance from the roadway, and at 300 ft range from about 9 to 12 $\mu g/m^3$. These values, it may be noted, are consistently highest for St. Louis, followed by Manhattan and Phoenix, although the variation among regions is not large. As a percentage of the 75 $\mu g/m^3$ TSP standard, the diesel contribution at the 25-percent dieselization rate and 300-ft position ranges from 12 to 16 percent (not shown in the tables).

An important study postulate that should be recalled at this point is that HDV's will be largely dieselized by the year 2000 (96 percent). Therefore they make a significant contribution to the diesel exhaust concentration shown in the table. Using the curves in Section 4.1 or the dump tables in Appendix D, the percent HDV contribution to the total diesel exhaust particulate concentration at the 25-percent LDV dieselization rate can be shown to range from 66 to 73 percent, applicable to all roadway positions. On this same theme, it may be recalled that HDV's were assumed to remain uncontrolled at a particulate emission rate of 2.0 g/mi. If HDV dieselization had been taken at 75 percent of the projected 2000 level, or if particulate control to 1.5 g/mi (75 percent) had been assumed, or if by any combination of these factors the HDV dump were reduced to 75 percent of the calculated levels, then the diesel exhaust concentration would be reduced by from 16 to 18 percent, applicable to all roadway positions. In terms of TSP for Manhattan at the 25-percent dieselization rate, this would result in concentration reductions of 6 percent (6 $\mu g/m^3$), 3.6 percent (3 $\mu g/m^3$), and 2.5 percent (2 $\mu g/m^3$) at the median, 100-ft and 300-ft positions, respectively. Smaller reductions are indicated for St. Louis and Phoenix.

Likewise, if the LDV/LDT particulate emission rate had been taken at 0.2 g/mi rather than 0.25 g/mi, as assumed in the study, the diesel concentration contribution would be reduced by from 5 to 7 percent at the 25-percent dieselization rate (all roadway positions). For Manhattan this would result in TSP reductions of 1.8 percent (2 $\mu g/m^3$), 1.1 percent (1 $\mu g/m^3$), and 0.8 percent (0.6 $\mu g/m^3$) at the median, 100 ft, and 300 ft positions, respectively. For all regions, the combined effects of both adjustments would be to reduce the diesel contribution by about 24 percent, a significant decrement in terms of diesel particulate concentrations, though small in relation to influences on TSP.

The effects of LDV dieselization may be gauged directly from the percent change in diesel concentration relative to the base case. At the 25-percent dieselization rate the diesel contribution increases for all roadway positions by 38 percent for Manhattan, by 35 percent for St. Louis, and by 49 percent for Phoenix. The changes in total vehicle contributions are somewhat smaller: 32 percent, 30 percent, and 41 percent, respectively. Both sets of changes are identical to those shown under areawide effects in Section 5.1. The percent change in total particulates is variable with roadway position and regional area. For 25-percent dieselization at the 300-ft position, these values become 3.7 percent for Manhattan, 3.4 percent for St. Louis, and 2.3 percent for Phoenix. Thus, relatively large increases are indicated for diesel exhaust concentration effects but relatively small increases are indicated for the concentration of TSP.

The effect of 100-percent dieselization of taxicabs in Manhattan is to increase the diesel exhaust concentration by about 17 percent relative to the exhaust concentration for the 25-percent standard scenario (all roadway positions). At the 300-ft roadway position, the concentration increases from 11 $\mu g/m^3$ to 12.9 $\mu g/m^3$, increasing the diesel contribution to TSP from 14 to 16 percent. Relative to the base case, taxi dieselization increases the diesel exhaust concentration by 61 percent, compared to 38 percent for the 25-percent dieselization scenario.

The values quoted in the preceding discussion must be viewed critically from the standpoint of their meaning relative to exposure effects impacting a significant fraction of the population. The annual geometric mean concentration is typically employed as a measure of long-term, general population impacts, whereas neither the median position nor the 100-ft roadway position are characteristic of conditions meaningful in this context. The 300-ft position may be regarded as a long-term exposure site, since residences are frequently located at these distances, but only a minute fraction of all housing is so situated.

In this sense, it is instructive to examine what would happen to the concentration levels in Table 5-7 if a traffic rate more representative of an areawide urban arterial network were used in place of the 188,000 daily traffic rate employed for the urban freeway in this study. Taking this rate at 25,000 veh/day, and assuming that the results of the freeway analysis will scale with traffic rate over a broad range, then the exhaust concentrations shown in Table 5-7 would decrease in the ratio 25/188. Thus, the diesel exhaust concentrations at 25-percent dieselization rate would reduce to levels on the order of 1 to 3 $\mu g/m^3$ at distances of 100 ft and beyond, or generally less than 3 percent of the TSP.

The results of the environmental assessment for urban freeway particulates may be summarized as follows. Absolute levels of annual geometric mean particulate concentration were established for all scenario cases by adding the exhaust particulate concentration for motor vehicle exhaust emissions to ambient background levels in the three regional areas studied under areawide effects. The Federal air quality standard of 75 $\mu g/m^3$ was found to be exceeded for every scenario case, including the base case, a result due solely to the fact that the ambient backgrounds in the three regions were near, at, or above the ambient standard level. This condition may be typical of many urban areas nationwide, so that dieselization to any degree tends to make the problem of meeting the TSP air quality requirement more difficult.

For the year 2000, diesel exhaust concentration contributions at the 25-percent dieselization rate range from a high at the roadway median position of from 28 to 35 $\mu g/m^3$ to a low of 9 to 12 $\mu g/m^3$ at 300 ft.

The 300-ft results represent contributions to the Federal air quality standard of from 12 to 16 percent.

The HDV contribution to the diesel-total exhaust concentration is extremely high, ranging from 66 to 73 percent (25-percent LDV dieselization rate). Control of HDV particulate emissions to the level of 1.5 g/mi, compared to the assumed uncontrolled rate of 2.0 g/mi, would reduce the diesel exhaust concentration by from 16 to 18 percent in the regions studied.

Relative to the base case in the year 2000, LDV dieselization at the 25-percent rate increases the diesel concentration contribution for all roadway positions by from 35 to 49 percent at the 300-ft position. These contributions have a minor impact on TSP, increasing the level by from 2.3 to 3.7 percent in the regions studied. Effects of this magnitude may be expected for urban areas nationwide.

The effect of 100-percent dieselization of taxicabs in Manhattan is to increase the diesel exhaust concentration by 61 percent relative to the base case. At the 300-ft roadway position, an exhaust concentration of about 13 $\mu g/m^3$ is produced. This compares to 8 $\mu g/m^3$ for the base case, an increase of 61 percent. The contribution to Manhattan TSP is 16 percent.

Following the procedure used for the urban freeway, absolute TSP concentration levels (annual geometric mean values) applicable to the three metropolitan regions studied were calculated for the street canyon traffic site. Motor vehicle exhaust emission concentration contributions were taken from Table 4-9 (best estimate of street canyon conditions nationwide), expanded to include all dieselization scenarios. These values were adjusted to reflect region-specific composite emission factors. TSP and other parameters useful to the assessment of environmental impacts are shown in Table 5-8 for the year 2000. Values are provided for three street canyon heights: street level, 30 ft, and 90 ft, representing locations near the street canyon building walls and therefore indicative of the quality of the atmosphere exposed to pedestrians and inducted for building ventilation.

Concentrations are highest at street level and decrease with height above street. With the exception of Manhattan at the 90-ft height, the TSP values for all scenario cases, including the basecase, exceed the Federal

Table 5-8. Street Canyon Particulate Effects, Year 2000 (Annual Geometric Mean Concentrations)

		Street Level (6 Ft)								30 Feet Above Street								90 Feet Above Street							
		Concentration, $\mu g/m^3$			% Contribution		% Change from BC			Concentration, $\mu g/m^3$			% Contribution		% Change from BC			Concentration, $\mu g/m^3$			% Contribution		% Change from BC		
Regional Area	Dieselization Rate	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T	Diesel (D)	Total Veh. (TV)	TSP (T)	D/T	TV/T	D	TV	T
Manhattan (Ambient = $67 \mu g/m^3$)	BC	8.7	9.8	77	11	13	--	--	---	7.1	7.9	75	9.5	11	--	--	---	4.2	4.7	72	5.8	6.6	--	--	---
	10%	10.0	11.0	78	13	14	14	12	1.6	8.1	8.9	76	11	12	14	12	1.3	4.8	5.3	72	6.6	7.3	14	12	0.8
	25%	12.0	12.9	80	15	16	38	32	4.0	9.7	10.4	77	13	13	38	32	3.3	5.8	6.2	73	7.9	8.5	38	32	2.1
	25% PC + 100% Taxis	14.0	14.9	82	17	18	61	53	6.6	11.3	12.0	79	14	15	61	53	5.5	6.8	7.2	74	9.2	9.7	61	53	3.5
St. Louis (Ambient = $75 \mu g/m^3$)	BC	9.4	10.5	86	11	12	--	--	---	7.6	8.4	83	9	10	--	--	---	4.5	5.0	80	5.6	6.2	--	--	---
	10%	10.7	11.7	87	12	13	13	11	1.4	8.6	9.4	84	10	11	13	11	1.2	5.1	5.6	81	6.3	6.9	13	11	0.8
	25%	12.7	13.6	89	14	15	35	30	3.6	10.3	11.0	86	12	13	35	30	3.1	6.1	6.5	82	7.5	8.0	35	30	1.9
Phoenix (Ambient = $121 \mu g/m^3$)	BC	6.9	7.8	129	5.4	6.0	--	--	---	5.6	6.3	127	4.4	4.9	--	--	---	3.3	3.7	125	2.6	3.0	--	--	---
	10%	8.2	9.0	130	6.3	6.9	19	15	0.9	6.6	7.3	128	5.1	5.7	19	15	0.8	3.9	4.3	125	3.1	3.4	19	15	0.5
	25%	10.1	11.0	132	7.6	8.3	49	41	2.5	8.2	8.9	130	6.3	6.9	49	41	2.0	4.9	5.3	126	3.9	4.2	49	41	1.3

All values for year 2000, Traffic count = 936 veh/hr (24-hour average)

BC - Base Case (1% LDV/.2% LDT dieselization,

PC - Passenger Cars

standard of 75 $\mu g/m^3$, by reason of the fact that the ambient concentration in the three regions studied is extremely high. As noted for the urban freeway, this condition is expected to be encountered in many areas, so that dieselization to any degree will generally add to the difficulty of meeting the air quality standard in the urban environment.

In general, the diesel exhaust concentrations are lower than those shown for the urban freeway and do not vary significantly among the metropolitan areas. For the 25-percent dieselization rate at the street level position, these concentrations are 12.0, 12.7, and 10.1 $\mu g/m^3$ for Manhattan, St. Louis, and Phoenix, respectively, representing 16, 17, and 13 percent of the air quality standard and 15, 14, and 7.6 percent of the respective regional TSP's. Relative to the base case, the change in diesel exhaust contribution is 38, 35, and 49 percent (these effects are applicable to all street canyon positions and are the same values quoted for the urban freeway). These increases, though large, produce changes in TSP of only 4.0, 3.6, and 2.5 percent in the three respective regions.

Concentrations at the 30- and 90-ft heights are, respectively, 81 and 48 percent of the street level values. The effect of controlling HDV emissions to 1.5 g/mi as compared to the 2.0 g/mi rate assumed in this study would be to reduce the diesel exhaust concentration at all locations by from 16 to 18 percent in the three regions studied (same values quoted for urban freeway). All of the diesel and total vehicle concentrations scale directly with traffic rate, which here has been taken at a level representing a very heavily traveled urban street (daily average traffic rate of 936 veh/hr).

The effect of 100-percent dieseization of taxicabs in Manhattan is to increase the diesel exhaust concentration by 17 percent relative to the 25-percent dieselization scenario and 61 percent relative to the base case (same values quoted for the urban freeway). The concentration is 14 $\mu g/m^3$ at street level, 11.3 $\mu g/m^3$ at 30 ft, and 6.8 $\mu g/m^3$ at 90 ft.

Whereas none of these concentrations appear to be very large, the health impacts of diesel exhaust have yet to be correlated with concentration and exposure, so that it is difficult to assess the meaning of these results with respect to possible health effects. On the issue of exposure, it is evident that these levels could represent exposure times of 8 to 10 hours a day for pedestrian and office workers and 24 hours a day for residents of the CBD. Whereas almost all modern office facilities are mechanically ventilated and these systems are equipped with filters that would extract much of the ambient particulate matter and some fraction of the diesel exhaust, older sections of the CBD (lower Manhattan, for example), are not so equipped, and these workers, presumably, would be subject to the indicated diesel concentrations for a full working day.

The results shown in Table 5-8 may be summarized as follows. TSP levels generally approaching or exceeding the Federal standard of 75 $\mu g/m^3$ are indicated at all street canyon elevations, a result due largely to the high ambient (non-vehicle-exhaust) concentration conditions in the metropolitan areas examined. This condition is expected to exist in many large metropolitan areas so that dieselization to any degree will add to the difficulty of attaining TSP air quality goals.

Diesel exhaust concentrations are generally lower than those indicated for the urban freeway. The maximum levels occur at street level where concentrations ranging from 10 to 13 $\mu g/m^3$ (13 to 17 percent of the air quality standard) are seen at the 25-percent dieselization rate. Relative to the base case, LDV dieselization at 25 percent increases the diesel exhaust concentration by from 35 to 49 percent. These increases, though large, result in TSP increases of only 2.5 to 4 percent in the regions examined. This effect is expected to hold for all urban areas nationwide.

No attempt is made in this study to project national population-averaged levels of exposure to the urban freeway and street canyon sources. However, as an illustration of how these may impact on the exposure level of an individual, consider the case of a resident of Queens, New York who travels 1-1/2 hours each workday on an urban freeway, spends 1-1/2 hours as a driver or pedestrian on Manhattan streets, and works 8 hours in a street canyon office located 30 ft above the street. This schedule is assumed to be followed 6 days a week (to account for some weekend exposure to elevated TSP levels) while the 7th day is assumed to be spent entirely in residence where the TSP concentration in the general area is 60 $\mu g/m^3$* (typical for central Queens). Using the results of Tables 5-7 and 5-8 for the Manhattan taxi scenario, it may be shown that the composite TSP exposure level of the individual is 70 $\mu g/m^3$ (annual geometric mean basis). Assuming that the diesel contribution to the residential TSP is proportional to the Manhattan diesel-to-total particulate dumps, it may also be shown that 10 percent of this exposure, or 7 $\mu g/m^3$, is related to diesel exhaust particulates. This compares to a 2 $\mu g/m^3$ annual mean diesel exhaust concentration if the exposure were confined to the residential area alone.

5.2.1.2 Parking Garage

Lacking experimental data, the enclosed parking garage was treated analytically. This approach provides no basis for determining statistical means or maximums, nor for referencing exhaust concentrations to statistically-based ambient air concentrations. Moreover, the controlled, filtered atmosphere in a mechanically ventilated garage may be virtually independent of urban atmospheric conditions. For these reasons, the impacts of dieselization for the enclosed parking garage are examined only in terms of concentation changes relative to an unspecified ambient level in the incoming ventilation air.

Table 4-13 summarized the exhaust particulate concentration effects due to off-peak garage activity. This table, which is based on Manhattan fleet statistics, indicates that diesel exhaust concentrations in the garage will peak in 1990 and that at a 25-percent LDV dieselization rate the diesel concentration would stabilize at the level of 35 $\mu g/m^3$, while the total vehicle (gasoline plus diesel) concentration would stabilize at 49 $\mu g/m^3$. It must be emphasized that the garage activity level Y selected for these computations represents unusually busy conditions. A best-estimate Y would produce concentration levels of about half those shown; i.e., 17 $\mu g/m^3$ and 24 $\mu g/m^3$ for diesel and total exhaust concentrations, respectively. These values are still relatively high, but the exposure of garage patrons is generally very

*Total for all sources

brief, typically on the order of a few minutes or less per day. These levels would present a more serious problem for parking garage attendants, but many garages are automated or provide specially ventilated facilities for garage personnel.

Figure 4-51 demonstrates that at rush hour conditions, when garage exit facilities become temporarily overloaded, total vehicle particulate concentration may temporarily peak above 400 $\mu g/m^3$ and levels over 100 $\mu g/m^3$ may persist for a period of 30 minutes. Typical times of exposure to such levels are probably less than 5 or 10 minutes. Nevertheless, these high levels could be a matter of concern.

Unlike the other traffic sites considered in this study, the parking garage offers a variety of means by which high exhaust concentration levels might be alleviated. The simplest means applicable to new structures is to institute more stringent ventilation rate requirements. The New York City Code requirement of 0.1 air changes per minute calls for a 50-percent higher ventilation rate than the Uniform Building Code rate of 0.067 min^{-1} that is presently accepted by many municipalities. It may be noted that if the New York City Code ventilation rate had been used in Table 4-13, the concentration levels calculated would have been about 50 percent lower than shown.

Higher ventilation rates or auxiliary ventilation equipment emplaced in critical garage sites such as exit ramps may also be feasible. The ASHRAE guide book (Ref. 5-1), addressing the problem of a queue of idling cars at the overloaded exit facilities of an enclosed garage, states that:

> The areas that generally develop the greatest CO and oil and gas fumes are the ramps to the outside. Ramps should be given from 10 to 20 air changes per hour of exhaust ventilation, for it is at these points that cars may not be moving, yet idling, for any period of time due to street traffic congestion. It may be desirable to consider the use of two-speed motors or auxiliary fan systems to supplement the ventilation requirements in case of emergency.

The ventilation rate of 20 air changes per hour quoted above is more than three times greater than the New York City code and five times greater than the Uniform Building Code requirement. It is not known if this recommended exit ramp treatment has been adopted in the building code of any municipality, but there appears to be no reason why it could not be.

In summary, garage exhaust particulate concentrations at the 25-percent LDV dieselization rate are predicted to reach (best estimate) levels of 17 $\mu g/m^3$ diesel and 24 $\mu g/m^3$ total vehicle, during periods of off-peak garage activity. At rush hour conditions, when garage exit facilities become overloaded, concentration levels may temporarily peak above 400 $\mu g/m^3$ and levels over 100 $\mu g/m^3$ may persist for 30 minutes. While driver exposure to these atmospheres is probably less than 10 minutes per day, the high concentrations could be a matter of concern. A simple means of alleviating these conditions is to increase garage ventilation rates and/or to provide auxiliary ventilation equipment at critical garage sites such as exit ramps. It thus appears that particulate concentration effects in the enclosed parking garage should be amenable to control so that this traffic site would not constitute a barrier to LDV dieselization at any of the production rates considered.

5.2.2 Odor

Odor analyses were performed for the urban freeway, the urban street canyon, and the enclosed parking garage in Sections 4.2.1.2, 4.2.2.2, and 4.2.3.2, respectively. In each case, the diesel exhaust concentration for the conditions of a nominal average mix of diesel and gasoline vehicles corresponding to the highest dieselization rate considered in this study was found to produce no detectable odor effects. Recognizing, however, that odor levels may be strongly influenced by short-duration localized concentrations and that in any random event a high fraction of diesel vehicles may occur, the case for a 100-percent diesel population was investigated. This investigation yielded ambient D-numbers of 1.5 for the urban freeway, 2.6 for the street canyon, and 1.8 and 4.0 for off-peak activity and overload conditions, respectively, in the enclosed parking garage. At a D-number of 2.0, the lowest value ranked for odor response, 56 percent of the subjects tested evaluated the odor as unpleasant or worse. At a Damb of 3.0, 73 percent of the subjects tested evaluated the odor as unpleasant or worse.

From these results, it is concluded that on a dieselized-nominal vehicle mix basis, diesel odor will not be a significant problem. However, localized high-level exhaust concentrations are likely to occur, producing odor effects generally regarded as unpleasant or worse by a large segment of the public. The odor effects tend to be least severe for the urban freeway, somewhat higher for the street canyon, and highest for the parking garage under exit overload conditions. The garage problem, it may be noted, can be treated by providing adequate auxiliary ventilation for use during exit rush episodes.

REFERENCE

5-1 ASHRAE Guide and Data Book: Applications, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, N.Y. (1971).

6. POSSIBLE DIESELIZATION CONSTRAINTS AND ASSOCIATED ENERGY IMPACTS

6.1 INTRODUCTION

The previous sections have investigated areawide pollutant dumps for several large cities and local air quality effects for sites where heavy vehicle concentrations occur. This section will discuss whether these results indicate a constraint on the possible extent of dieselization due to environmental factors.

The aforementioned analyses assumed a fixed set of emission factors (emissions/mi), VMT, etc. There will always be some uncertainty about such values when projected so far into the future. In addition, for some critical pollutants such as NO_x and particulates, the emission factors selected were based on current experience and/or anticipated standards. Whether or not these assumed values adequately represent the future is, of course, uncertain. For instance, improvements in emission control may occur in the future or the standards may not be achieved. A critical item in the latter category is the LDV particulate emission factor. The automobile manufacturers indicated at recent hearings that they do not believe the proposed EPA standard of 0.2 g/mi (0.25 g/mi assumed in this study) can be met in the near future (Ref. 6-1). This section therefore will also examine the sensitivity of potential environmental constraints to variation in critical parameters such as emission factors.

Finally, an assessment will be made of the impact on U.S. fuel consumption if environmental or regulatory constraints were to limit the number of diesel LDV's and LDT's produced and sold.

6.2 DIESELIZATION CONSTRAINTS INDICATED BY STUDY RESULTS

6.2.1 Hydrocarbons and Carbon Monoxide

Pollutant effects due to diesel HC and CO emissions appear to pose no problems for any of the cases considered or anticipated to be significant. Dieselization is projected to improve air quality relative to these two pollutants.

Maximum ambient CO values tend to be local and are associated almost entirely with mobile sources. Local site CO effects were not specifically evaluated but can be gauged, for example, from the areawide dump reduction in Phoenix where CO was reduced by almost 17 percent for the 25-percent dieselization scenario in the year 2000.

Hydrocarbon emissions are of significance primarily because of their role in oxidant formation. Oxidant formation takes an appreciable time, requiring pollutant mixing and dispersion to occur, so that it tends to be an areawide problem; therefore, the reduction in areawide dump is a significant measure of the impact of dieselization on oxidants. For the regions studied, reductions in HC ranging from 3 to 9 percent (25-percent dieselization rate, year 2000) were indicated. The conditions examined are expected to encompass effects in most urban areas with severe oxidant problems, although in cities such as Houston, where the bulk of the HC emissions are associated with refineries and large petrochemical complexes, dieselization will have little positive impact.

As discussed in Section 5, these reductions of HC and CO come about as the result of the replacement of gasoline vehicles by diesel vehicles with lower projected lifetime emission rates. In the time frame encompassed by the study, improvements in gasoline vehicle emission control may take place, which would offset the HC and CO reductions quoted above. It is perhaps unlikely, however, that gasoline emissions can ever be reduced to diesel emission levels due to the inherent deterioration problems associated with catalysts.

6.2.2 Benzo(a)pyrene

BaP emissions were projected to increase with LDV dieselization. The impact of the vehicle contribution relative to total source emissions could not be evaluated for lack of information on stationary source emission contributions in the regions studied.

No standard for BaP or other PNA emissions exists, due to uncertainty as to the health impacts of these pollutants. BaP is suspected of being a carcinogen and in the long time frame of this study new health effects data may result in an emissions standard for this pollutant. At present, however, there is no basis for determining if the increased level of BaP emissions due to dieselization constitutes a constraint on the number of diesel vehicles that could be produced.

6.2.3 Oxides of Nitrogen

The results of the study indicate that there is a reduction in the areawide dump of NO_x with increasing dieselization. The effect is relatively small and derives as follows.

The LDV diesel emission standards postulated in the study were 1.5 g/mi until 1985 and 1.0 g/mi thereafter. By comparison, a 1981 or later model year gasoline LDV is projected to have a lifetime average NO_x emission rate of 1.4 g/mi (MSEF, Ref. 6-2). These assumptions account for the reduction in NO_x with dieselization. If the diesel emission standards postulated are not met and if the required waivers are granted, then the trend of NO_x with dieselization could be reversed. It may be noted that the diesel rate could be increased to 1.4 g/mi without exceeding the lifetime average emissions of an equivalent gasoline vehicle. At 1.5 g/mi, dieselization would produce a slight increase in the NO_x dump, with a net effect on air quality which would be quite small in the regions studied, because of the relatively large NO_x contribution by stationary sources. This small effect would be expected to hold for most urban areas with a NO_x problem.

Table 6-1 shows the effects of increasing the diesel LDV and LDT NO_x emission standards by 50 percent (to 1.5 g/mi for LDV) for post-1981 vehicles. The table has been prepared for the year 2000 when the effects of dieselization are maximized. It may be seen that the effect on the total vehicle NO_x dump is quite small and the effect on the regional area NO_x dump is smaller still. These considerations suggest that NO_x emissions would not constrain diesel production up to the maximum levels considered in the study.

Table 6-1. Percentage Increase in NO_x Emissions for a 50-Percent Increase in Diesel LDV/LDT Emission Factor, Year 2000

Regional Area	Dieselization Rate	Percent Increase*	
		Total Vehicle NO_x Emissions	Regional Area NO_x Dump
Manhattan	10%	2.8	0.30
	25%	7.2	0.75
St. Louis	10%	2.7	0.18
	25%	6.9	0.46
Phoenix	10%	2.7	1.63
	25%	7.1	4.22

*Referenced to NO_x dump calculated in this study

6.2.4 Odor

At present, there are no EPA standards for odor, but such standards might be promulgated in the future if a serious diesel odor problem were identified. This is not anticipated, however. As discussed in Sections 4 and 5, high odor levels may be encountered locally under the conditions where unusually heavy concentrations of diesel vehicles occur in areas with inadequate ventilation, such as at a garage exit during the evening rush hour. An increase in ventilation rate can obviate such problems. Thus, odor is not regarded as a fundamental constraint on dieselization.

6.2.5 Particulates

Diesel particulates may be of concern with regard to health effects for several reasons. They contribute to the total particulate dump and therefore to possible irritant and toxicological effects. Because of their very small size, they are much more likely to be drawn deep into the lungs and retained. Also, they are suspected of being carcinogenic in nature. To date the health consequences of the latter two concerns are largely unknown and have not been considered as a fundamental justification for setting an emission standard.

With regard to areawide dump effects, diesel particulates add very little to the TSP dump of the metropolitan regions investigated in this study. This would hold even if the 0.25 g/mi particulate emission rate assumed for diesel LDV's and LDT's in the study is not met and emission rates of 0.5 to 0.7 g/mi were the best obtainable. Table 6-2 shows the percentage increase in total vehicle and total (areawide) particulate dump that would occur if the LDV and LDT emission factors were taken at 0.5 and 0.7 g/mi. It may be seen that the effect on areawide emissions is very small.

Though diesel particulates exhibit a somewhat greater influence on local site conditions, as discussed in Section 5, the effects at positions identified as having long-term exposure impact also appear to be small. Taking the Manhattan street canyon site at 30 ft (possible apartment heating/ventilating system intake elevation), for example, the total diesel contribution (including HDV) at 25-percent dieselization rate in the year 2000 is

Table 6-2. Percentage Increase in Particulate Emissions for 0.5 and 0.7 g/mi LDV/LDT Emission Factors, Year 2000

Regional Area	Particulate Emission Factor g/mi	Diesel-ization Rate	% Increase in Particulate Emissions*	
			Total Vehicle Exhaust	Regional Area Dump
Manhattan	0.5	10	12.6	0.31
	0.5	25	26.5	0.77
	0.7	10	22.6	0.56
	0.7	25	47.7	1.4
St. Louis	0.5	10	11.8	0.04
	0.5	25	25.2	0.09
	0.7	10	21.2	0.06
	0.7	25	45.3	0.16
Phoenix	0.5	10	15.5	0.06
	0.5	25	31.8	0.14
	0.7	10	27.9	0.10
	0.7	25	57.2	0.25

*Referenced to particulate dump calculated in this study.

9.7 $\mu g/m^3$ or 13 percent of the TSP concentration (Table 5-8). The LDV/LDT contribution, which may be derived from the dump tables of Appendix D, is considerably smaller at 2.8 $\mu g/m^3$, representing 3.6 percent of the TSP concentration or 3.7 percent of the primary air quality standard. If the LDV/LDT emission rate were 0.5 g/mi instead of the assumed 0.25 g/mi, these values would become 5.6 $\mu g/m^3$, 7.2 percent of the total concentration, and 7.4 percent of the primary air quality standard.

These results, taken in context with the more extensive discussion of Sections 5.1.1 and 5.2.1, do not identify a constraint on LDV dieselization due to particulate emissions, and none will be assumed in the treatment of diesel fuel savings foregone.

It may be argued that in principle diesels are unacceptable since they do cause an increase, however small, in urban particulate levels which in many regions are already high. A diesel constraint based on regional considerations might then be proposed, and the energy savings foregone could be calculated considering those regions where the addition of diesels would cause TSP to exceed the primary standard. This kind of an approach would require the resolution of such issues as, which class of vehicles shall be constrained; i.e., LDV/LDT, HDV, or both? Which GVWR HDV's in classes 2 through 8 should be constrained? How could such constraints be implemented considering intercity commercial and private travel? The determination of these factors is well beyond the scope of the present effort and is not attempted.

6.3 FUEL SAVINGS FOREGONE

The preceding review of environmental impact indicated by the results of this study did not identify any constrains on LDV dieselization due to environmental factors. However, such constraints may develop if diesel vehicles are unable to meet the NO_x control requirement of 1.0 g/mi or the proposed particulate emission standard of 0.2 g/mi, or if future health effects studies determine that diesel particulates at the concentration levels characterized in this report are harmful. Accordingly, the following paragraphs examine, in a parametric sense, the fuel savings that would be lost if various elements of the LDV/LDT diesel sales market were barred from exploitation as a result of regulatory constraints on diesel vehicle emissions.

6.3.1 LDV

In general, the determination of fuel savings foregone depends on the anticipated diesel market penetration if there had been no constraint on dieselization. Specifying only the percentage of total LDV sales that are diesel is not sufficient to determine the fuel savings. It is also necessary to specify the percentage of sales in the various vehicle size classes, since fuel consumption varies markedly over the size range between subcompact and full size cars. Three conditions or cases for unconstrained diesel sales will therefore be considered: (1) diesel sales as a constant percentage of sales in all vehicle size classes, (2) diesel sales volume as identical to the first case but all diesel sales occuring in the full-size class, and (3) diesel sales volume as indentical to first case, but all diesel sales occuring in the subcompact class. As discussed in Appendix A, case 2 appears to be an attractive strategy for the automobile manufacturers, since it does much more to improve their CAFE than dieselizing a subcompact and is very important to them economically, since it maximizes the chances of preserving the more profitable large car lines. Case 3 is likely if the standard established for diesel particulate emissions is stringent. Particulate emissions are highly dependent on engine size so that subcompacts are much more likely to meet a stringent standard than larger cars. The assumptions and data sources for the results for all cases are shown in Table 6-3.

Figure 6-1 shows that annual fuel savings foregone if all LDV diesel vehicles were prohibited from sale, for the case where the unconstrained diesel sales percentage is assumed to be the same in all size classes (Case 1). The savings foregone are substantial. In the year 2000, at the 25-percent dieselization rate reference, the fuel savings foregone is 3.3 billion gallons/yr or approximately 5.0 percent of the fuel that would be consumed by an all-gasoline LDV fleet.

Table 6-3. Assumptions and Data Sources for Figures 6-1 through 6-4

Vehicle Survival and Annual Mileage Data	Reference 6-3 LDV data used for both LDV and LDT.
Annual Domestic LDV Sales	11×10^6 veh/yr to 1985, increasing at a linear rate to 14×10^6 veh/yr in 2000 (approximately the rates of Ref. 6-3).
Import LDV Sales	15% of domestic production.
LDT Sales	30% of LDV sales (~ current rate).
Fuel Economy for Gasoline LDV	Linear increase from 1980 CAFE standard to 27.5 mpg in 1985; 27.5 mpg thereafter, all divided by 1.11 to account for difference between certification and road values (Ref. 6-3).
Fuel Economy of Gasoline LDT	15 mpg in 1980 increasing linearly to 19.5 mpg in 2000 (less than CAFE; reduced by factor of 1.2 to account for payload and other effects Ref. 6-4).
Fuel Economy of Diesel LDV and LDT	25% greater than comparable gasoline vehicles (Ref. 6-3).
Projected Class Sales, Inertia Weights and Engine Displacement	Reference 6-3.
Fuel Economy Effects of Vehicle Size	$\propto (IW)^{-0.85}$, $0.4\left(\Delta \frac{CID}{IW}\right)$ (Ref. 6-3)

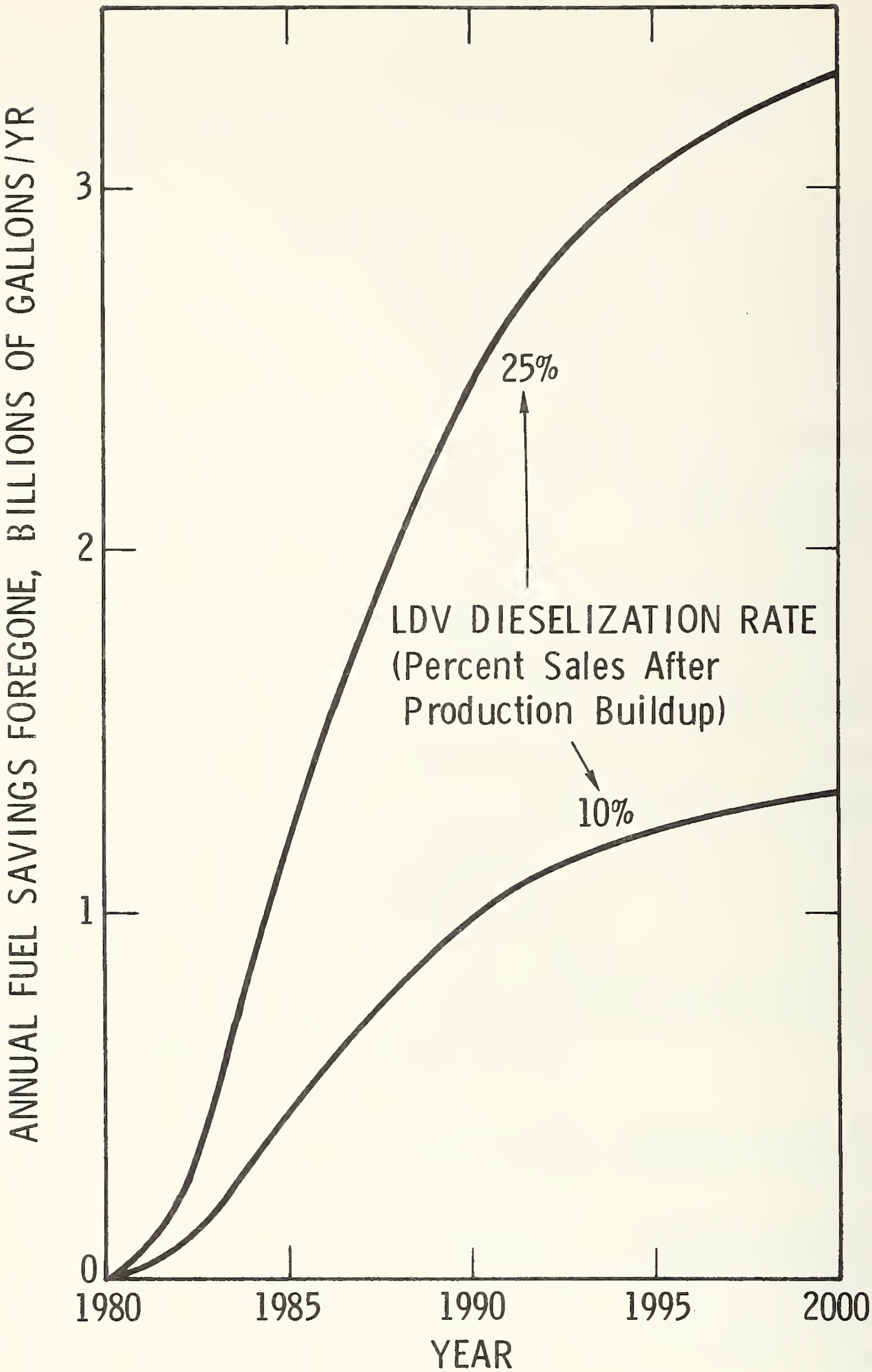

Figure 6-1. LDV Diesel Fuel Savings Foregone -- Based on Same Percentage Diesel Sales in All Market Classes

Figure 6-2 displays the fuel savings foregone if all LDV vehicles were prohibited from sale, for the case where unconstrained diesel sales are assumed to be confined to the full-size passenger car class (Case 2). For the same percentage dieselization of the total passenger car fleet, the savings are markedly greater than in Figure 6-1, due to the much larger fuel consumption of full-size cars. In the year 2000 at the 25-percent dieselization rate reference, the fuel savings foregone is about 4 billion gallons/yr or 6.1 percent of the fuel that would be consumed by an all-gasoline LDV fleet.

Figure 6-3 compares cases (2) and (3), in which diesel sales are all in either the full-size or subcompact size class. It is evident from the figure that a stringent particulate standard which only the subcompact can meet will severely reduce the fuel savings achievable by dieselization. The cases shown assume diesel sales of 25 percent of total sales in either class. This large a percentage of total sales in one class may not be possible, particularly for the subcompact; this vehicle class has not been that big a fraction of total sales for the domestic manufacturers. It may be noted that the importers, who largely sell subcompacts, do not have the same incentive to dieselize as the domestic manufacturers because of their already good CAFE. This factor may further heighten the adverse impact of a stringent particulate emission standard on the fuel savings possible with dieselization.

6.3.2 LDT

Figure 6-4 shows the fuel savings foregone if LDT diesels were prohibited from sale, assuming that the market penetration for unconstrained diesel sales was uniform among all LDT size classes. The fuel savings which would be lost in the year 2000 at the 25-percent dieselization rate is about 1.3 billions of gallons/yr, or 5.0 percent of the fuel that would be consumed by an all-gasoline LDT fleet.

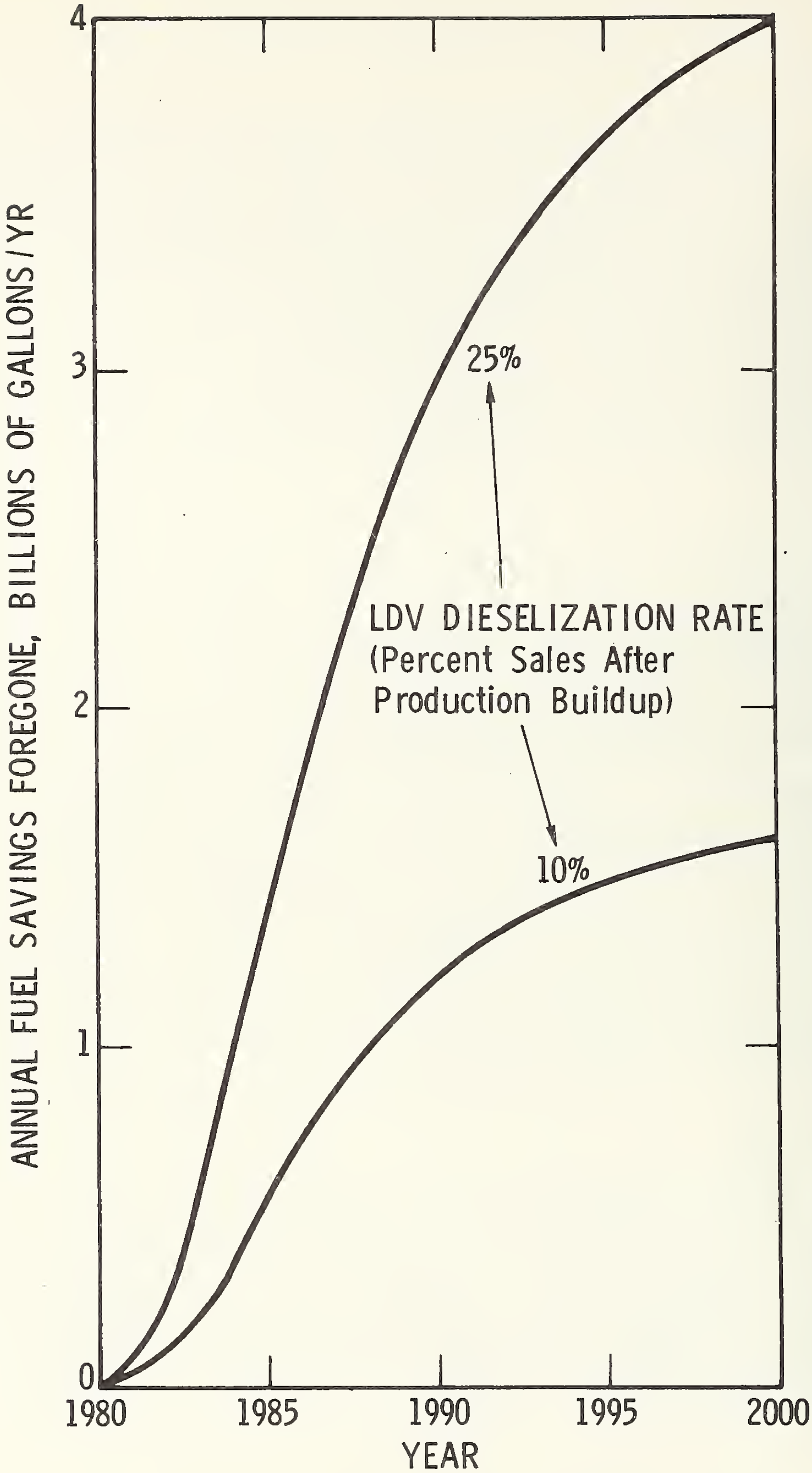

Figure 6-2. LDV Diesel Fuel Savings Foregone -- Based on All Diesel Sales in Full-Size Market Class

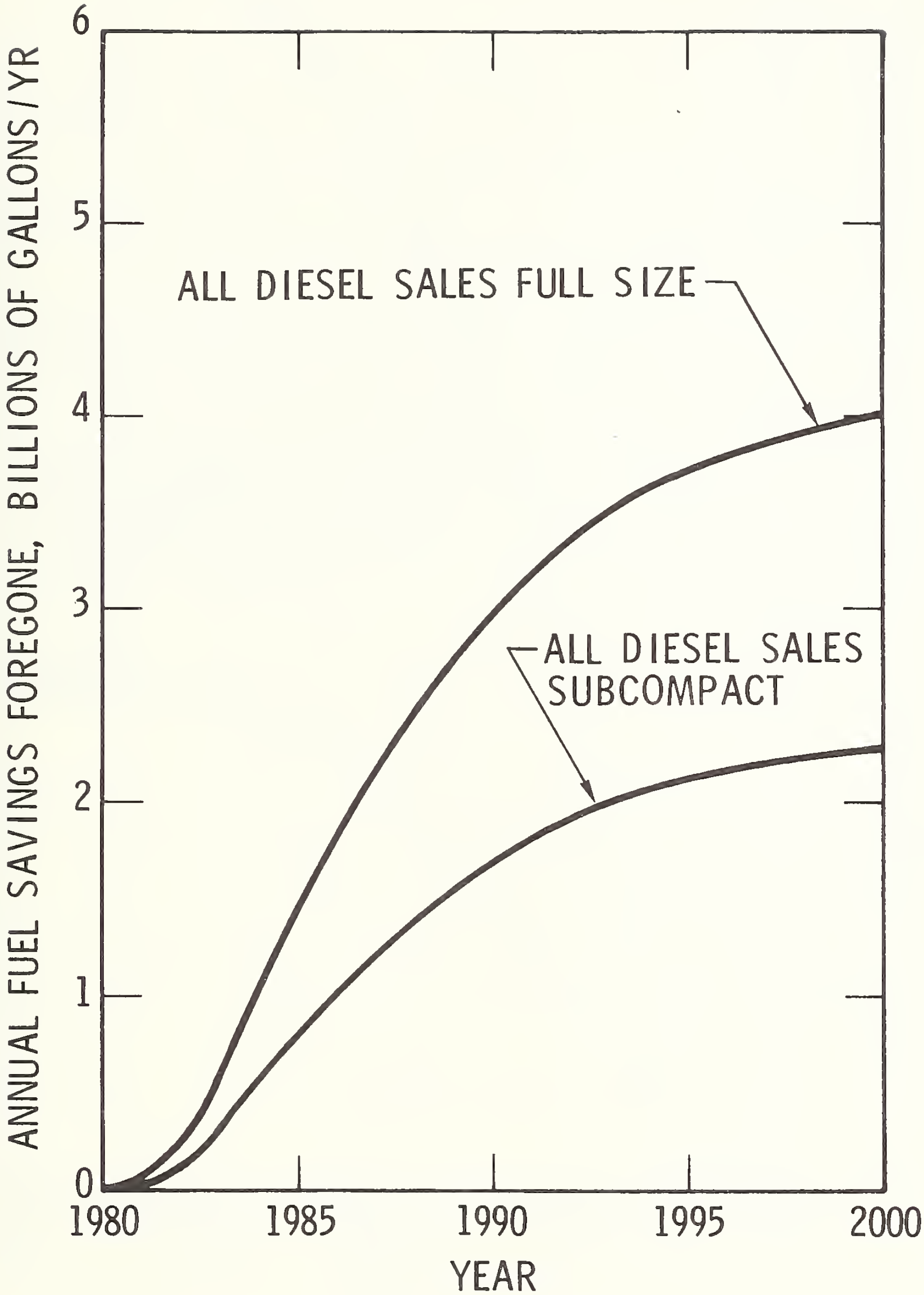

Figure 6-3. LDV Diesel Fuel Savings Foregone -- Based on 25 Percent of Diesel Sales All in Full-Size vs All in Subcompact Market Class

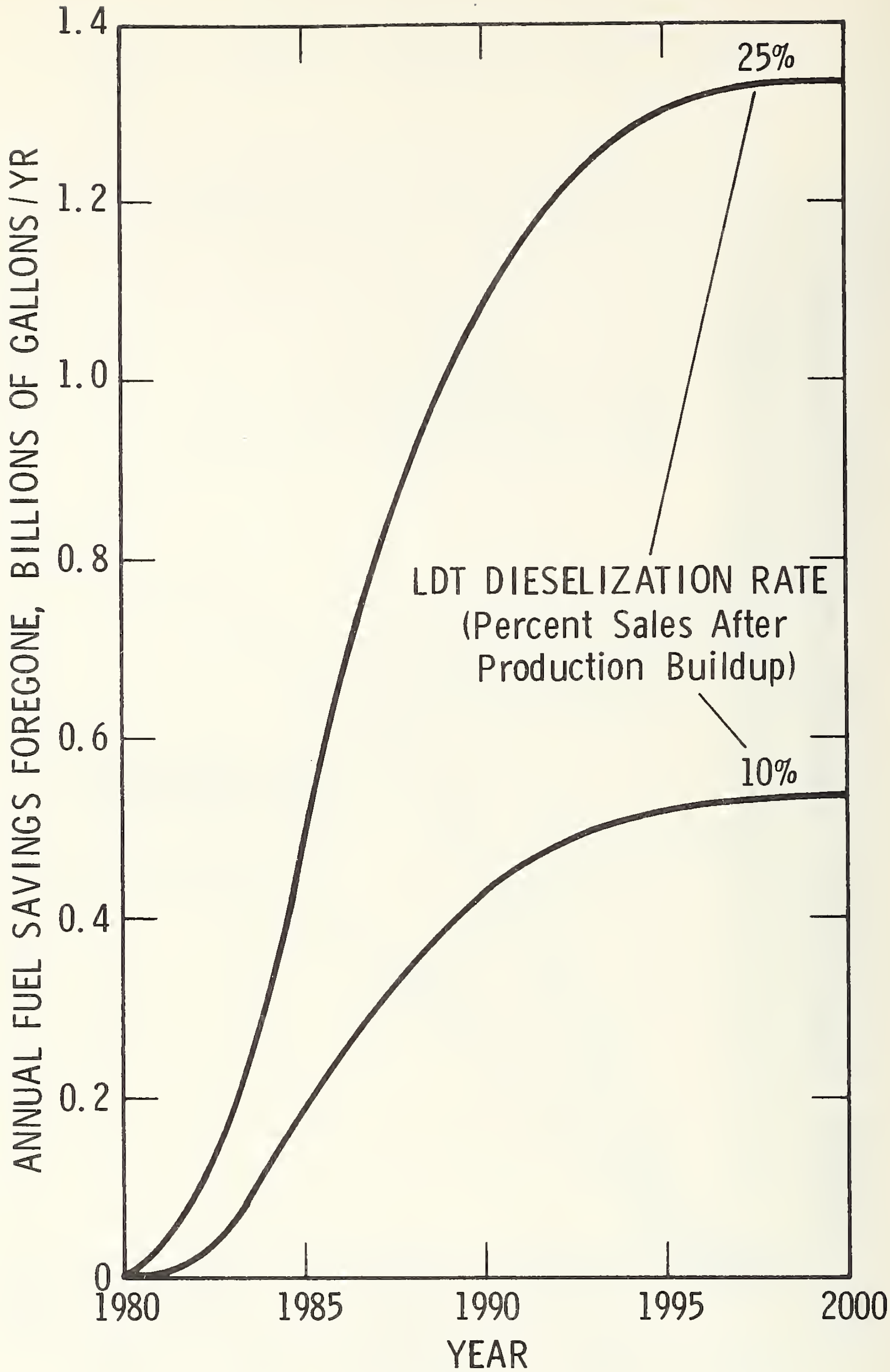

Figure 6-4. LDT Diesel Fuel Savings Foregone -- Based on Same Percentage Diesel Sales in All LDT Market Classes

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6-1 "Soot Proposal Will Kill Diesel, Detroit Says," Automotive News (26 March 1979).

6-2 Mobile Source Emission Factors, EPA-400/9-78-005, Office of Transportation and Land Use Policy, U. S. Environmental Protection Agency (March 1978).

6-3 Rulemaking Support Paper Concerning the 1981 - 1984 Passenger Auto Average Fuel Economy Standards, National Highway Traffic Safety Administration, Washington, D.C. (July 1977).

6-4 James J. Donnelly, Jr. and Wolfgang U. Roessler, "Fuel Consumption and Engine Horsepower Projections for the Highway Transportation Sector." Prepared by The Aerospace Corporation for Heat Engine Systems Branch, Office of Highway Systems, Division of Transportation Energy Conservation, U.S. Department of Energy (28 April 1978).

APPENDIX A

POSSIBLE LEVELS OF LDV DIESELIZATION

The diesel engine gives excellent fuel economy, particularly at part load where automobile engines usually operate. The reasons for this good fuel economy are the absence of throttling losses (power is varied by varying fuel-air ratio rather than throttling) and its high compression ratio. In spite of its superior fuel economy in the 85 years since the diesel cycle was patented, the engine has seen only relatively minor use in passenger cars. The reasons for this are that, compared with a gasoline engine, it is heavy, expensive to manufacture, noisy, hard to start in cold weather; its exhaust has a disagreeable odor and is sometimes smoky; it gives poor acceleration performance (for the same engine displacement); and fuel is sometimes not conveniently available due to its limited use.

In recent years, interest in use of the diesel for passenger cars has increased markedly. At first, the interest was because of the passage of the Clean Air Act of 1970, with its requirements for a large reduction in automobile emissions. The diesel can achieve the required emission level for HC and CO without exhaust aftertreatment devices, but cannot meet the presently mandated 1.0 g/mi NO_x standard for 1981+ in all vehicle size classes. The NO_x standard can be waived by the EPA administrator to 1.5 g/mi (which the diesel can achieve) but only for four years and with a finding of no danger to public health and providing there is a potential to exceed the fuel economy standards.

More recently, interest in the diesel for automobiles has further heightened with the passage of the 1975 Energy Policy and Conservation Act which requires dramatic improvement in automotive fuel economy. Fuel economy must be improved significantly with each model year between 1978 and 1985. Primarily because of the fuel economy requirements, GM introduced a 350 CID diesel engine in 1978 and a 260 CID diesel engine in 1979, while Chrysler has revealed plans to introduce a 225 cu. in. engine in the early 1980's.

The following paragraphs examine the major factors which will influence the extent of future dieselization of the automotive fleet.

A.1 INFLUENCE OF FUEL ECONOMY STANDARDS

Average fuel economy standards for a manufacturer's model year fleet presently are set for model years 1978 through 1985. They are 18 mpg in 1978 and 27.5 mpg in 1985. For the intervening model years, the standard increases more rapidly early on. Standards for 1986 through 1988 may be promulgated in August 1981 (Ref. A-1). The support document for the standards so far selected (Ref. A-2) indicates no dieselization is necessary. The automobile manufacturers, however, have objected to many of the assumptions used in determining the standards, so they may plan dieselization to some degree. Statements to date by the manufacturers do not indicate that any large-scale commitment to the diesel has yet been made. General Motors has been the most active and perhaps has the most incentive because, if present mixes of large and small vehicles are even approximately maintained, they have a more difficult job in meeting the fuel economy standards in that a much larger proportion of their sales consists of large cars. Sample calculations indicate that if present mixes are maintained and if GM found it necessary to dieselize at 25 percent of total sales to meet the 1985 standard, then the other manufacturers would not need to sell any diesels in order to meet the standard (25-percent fuel economy improvement with the diesel assumed). This, of course, does not preclude the possibility that other manufacturers will sell some diesels as a means of enlarging their large-car market share. Large cars are more profitable than small cars.

Ford has indicated they feel their PROCO stratified charge engine on balance is superior to the diesel and if their planned introduction of it is successful, they would not pursue the diesel.

The influence of post-1985 standards on dieselization rates is unknown, since the standards have not yet been set.

A.2 FUEL ECONOMY IMPROVEMENT POSSIBLE WITH THE DIESEL

The diesel is generally acknowledged to have a 25-percent fuel economy advantage over a current gasoline engine and drive train, assuming both engines are designed to give comparable vehicle performance and if fuel economy is expressed in mpg. However, this advantage is reduced to approximately 15 percent if fuel economy is expressed in terms of fuel energy, since diesel fuel has a higher energy content per gallon than gasoline. To date, EPA has elected to express fuel economy in mpg, since the energy expended at the refinery to produce diesel fuel at today's gasoline/diesel fuel sales ratios is less than to produce gasoline. Taking this energy loss into account, the barrels of crude oil saved by replacing a gasoline engine with a diesel would be approximately 25 percent.* In the future, the relative energy advantage for diesel fuel production may not exist. Refinery energy efficiency is a function of gasoline/middle distillate volume ratio (automotive diesel fuel is a middle distillate). Projections of future requirements indicate a marked increase in distillate production relative to gasoline, even without any sizable production of diesels for passenger cars. This is because of the large improvement in automotive fuel economy anticipated as a result of the 1975 Energy Policy and Conservation Act and because of increased jet airplane, diesel truck, and home heating fuels requirements. According to Reference A-3, this change in gasoline/distillate ratio in a 1995 scenario will result in no refinery energy savings for diesel cars and, in fact, at 30-percent diesel market penetration, significant refinery energy and cost penalties are incurred. Under these conditions, the fuel economy advantage expressed in barrels of crude oil required would be reduced to 15 percent. In the very long term, the refinery energy efficiency maximum according to Reference A-4 will occur at an even greater gasoline/distillate ratio as synthetic crudes become a significant feedstock for refineries.

This advantage is likely to be further reduced by the planned introduction of technological improvements for the gasoline system which either do not apply to the diesel system or do not offer the same degree of improvement for the diesel. An example of the former is electronic timing

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*However, much of the energy used for refining is derived either from waste products which would be discarded (flared or otherwise dissipated) if not used in a process application, or from fuels which are more economical than oil.

control. Another example is that as lead in gasoline is phased out, there may be a return to a multigrade gasoline supply. This would permit a return to higher gasoline engine compression ratios. An example of the latter type of improvement has to do with the major reason for the difference in fuel economy between gasoline and diesel engines. That is, diesel engines, having no throttle, suffer no throttling loss; hence they have much better fuel economy at low power levels. Therefore, innovations such as 4-speed or wide-range 3-speed automatic or CV-type (Continuously Variable) transmissions offer greater improvement for gasoline engines, since they reduce throttle loss by increase-ing average brake mean effective pressure.

The exact long-term fuel economy advantage of the diesel is difficult to determine precisely because of the uncertainty in what improvements will be made to the gasoline engine between now and when the diesel could be introduced in large quantities, and (as will be discussed later) uncertainties as to what future diesel NO_x emission requirements will be.

A.3 INFLUENCE OF DIESEL ECONOMICS ON POSSIBLE FUTURE SALES

It is evident from the introductory discussion that, as opposed to past automotive technological innovations (such as automatic transmissions, power steering, V-8 engines, etc., which offered comfort, convenience, or performance), the diesel must be sold to the consumer on the basis of the economics of fuel savings and reduced maintenance.

Most analyses of the costs of diesel ownership relative to a gasoline car show either equivalent or reduced costs for the diesel. Such results, however, are somewhat misleading, so far as economic attractiveness to the new car buyer is concerned. These analyses typically balance off fuel and maintenance savings over the entire life of the car against the higher purchase price of the diesel car. This is subject to several errors. One is that the original purchaser typically owns the car for only one-half its mileage life, so that fuel and maintenance savings over the last half of the car's life are not of concern to him. Another error is that people do not value future expenses (e.g., fuel and maintenance costs) the same as present costs (e.g., purchase price). Some analyses attempt to allow for this by discounting future expenses, typically 10 percent per year. This discounting appears inadequate. One reason for this inadequacy is that the price elasticity for automobiles is ignored. Price elasticities for automobiles range from - 1.5 to +0.1, generally speaking, suggesting that consumers overall have not been especially responsive to higher prices. However, a price difference beyond a certain value might discourage informed consumers from buying diesels because this price difference could overcome the savings associated with the reduced consumption and lower cost of diesel fuel.

There is disagreement on the price differential of a diesel. General Motors says $750 and others point to VW at $175. The $300 to $400 range is believed consistent with the VW cost. The VW cost is for a 4-cylinder engine, while the larger American cars most likely to be dieselized are 6- or 8-cylinder types, having from 50 to 100 percent more parts. These larger, more luxurious cars may require more soundproofing, thereby increasing the price differential. Past analyses have typically assumed diesel fuel selling at a significantly lower price than gasoline (5¢/gal differential). However, in the future when the demand for middle distillate is expected to grow relative to gasoline, the refinery economic results of Reference A-4 indicate no price advantage for diesel fuel. On the other hand, a general increase in the price of all fuels tends to make fuel-efficient vehicles more attractive.

Most analysts show a maintenance cost advantage for the diesel primarily because of the savings on spark plugs and tuneups. However, General Motors (Ref. A-5) shows no maintenance cost saving due to a much more frequent oil change requirement for the diesel (because of particulate contamination). Most of such maintenance cost comparisons are questionable in any case, because they are based on manufacturer's maintenance schedule recommendations, and the typical owner does not follow these guidelines.

It has been suggested that the automobile manufacturers might be motivated to a pricing strategy in which part of the price of a diesel is absorbed to encourage sales of larger cars with a greater profit margin while still meeting the fuel economy standards. A first-order analysis indicates this stratagem is of limited attractiveness, particularly if a continued decline of the dollar relative to the yen and the deutsche mark permits further increases in small-car prices relative to large-car prices.

In sum, the foregoing discussion indicates that solely from an economic standpoint, a diesel car is not expected to be particularly attractive to the informed new car buyer.

A.4 IMPACT OF CURRENT AND POSSIBLE FUTURE EMISSION AND FUEL ECONOMY REGULATIONS ON DIESEL SALES

Presently promulgated automotive emission standards call for a NO_x emission standard of 1.0 g/mi, beginning in the year 1981. A one-time-only 4-year waiver up to 1.5 g/mi for a diesel or other innovative technology is possible on a finding by the EPA administrator of no health danger and significant fuel economy benefits. Current technology does not permit achieving the 1.0 g/mi standard (except in very small vehicles) without an excessive fuel economy penalty and/or increased HC emissions. The uncertainty of obtaining the waiver and its limited duration may significantly inhibit the large-scale implementation of dieselization.

Among the pollutants emitted by the diesel engine in significantly larger quantities than the gasoline engine are: particulates, noise, sulfates, odor, and possible carcinogens and eye irritants. The technology for control of many of these emissions is not well developed. On the plus side, evaporative HC emissions should be less for diesel-fueled vehicles due to a much lower fuel vapor pressure. The significance of this, however, is dependent on gasoline distribution system evaporative emission control systems in place prior to possible dieselization.

A.5 ASSESSMENT OF THE LIKELY EXTENT OF FUTURE DIESELIZATION OF PASSENGER CARS

It is evident from the foregoing discussion that a number of factors, some positive and some negative, could influence the extent of passenger car dieselization. The magnitude of these influences is unknown at the present time. Among the issues in question are: What will the post-1985 fuel economy standards be? Will oil prices increase enough to cause a major shift in consumer attitudes toward fuel economy? How much competition will other new engine types such as PROCO offer the diesel? Will the NO_x standards kill interest in the diesel? What will the fuel economy state of the art of the gasoline engine be before dieselization can occur? Are the long-term projections for nonpassenger car distillate requirements correct?

In the face of all these unknown, it is uncertain that the automobile manufacturers can or will make a sudden large-scale commitment to the diesel. It may be more likely that it will be treated as one of many options for improving fuel economy, and will be introduced tentatively into the marketplace, with its future dependent on a complex, emerging scenario. This is consistent with past industry attitudes when past introductions of major technological innovations have been cautious and incremental because of the large financial and other risks associated with the scale of production and costs in the automotive industry. The weaker firms, by many accounts, could not survive a major marketing or technological mistake.

In view of the many uncertainties discussed in the foregoing, it is not possible to predict a likely upper-limit level for LDV dieselization. Considering the possible flaws in any such judgment, and to ensure that all plausible cases are considered, this study has adopted scenarios up to and including a market penetration of 25 percent.

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APPENDIX B

MODELS AND DATA EXAMINED FOR POTENTIAL VALUE IN ANALYZING LOCAL URBAN TRAFFIC SITES

This Appendix lists the mathematical models and measured roadway data bases examined in this study for possible application to the analysis of the urban freeway and the urban street canyon. For reasons delineated in Section 3.1.1.1, the use of a mathematical model approach was rejected in favor of an empirical analysis based on experimental data. The data bases selected for use in this analysis are described in Sections 3.2.2 and 3.3.2.

Table B-1. Mathematical Dispersion Models Examined, Urban Freeway

Model	Developed By	Reference
HIWAY	U. S. Environmental Protection Agency	B-1
"A Simple Line-Source Model for Dispersion Near Roadways"	General Motors	B-2
"An Advection-Diffusion Model for Pollutant Dispersion Near Roadways"	General Motors	B-3
CALINE-2	California Department of Transportation	B-4
TRAPS	Texas A& M University	B-5
AIRPOL-4	Virginia Highway and Transportation Research Council	B-6
TSC/EPA	U. S. Department of Transportation, Transportation Center Systems	B-7
"Simplified Analysis Technical for Estimating CO Concentrations Near Highway Facilities"	U. S. Department of Transportation, Federal Highway Administration	B-8
AVQUAL	Aerovironment, Inc.	B-9
"CEM Highway Traffic Air Pollution Model"	Center for the Environment and Man	B-9
EGAMA	Environmental Research and Technology, Inc.	B-9
"ESL Highway Microscale Dispersion Model"	Environmental Systems Laboratory	B-9
	General Electric	B-9
	Intera	B-9

Table B-1. Mathematical Dispersion Models Examined, Urban Freeway (Cont'd)

Model	Developed By	Reference
"KSK Line Source Model"	Kaman Sciences Corporation	B-9
"Lockheed Pollution Dispersion Model"	Lockheed Missile and Space Company, Inc.	B-9
"SCI Highway Air Dispersion Models"	Systems Control, Inc.	B-9
EXPLOR	Systems, Science and Software	B-9
"Walden Highway Model"	Walden Research, Inc.	B-9
	The Research Corporation of New England	B-10

Table B-2. Mathematical Dispersion Models Examined, Street Canyon

Model	Developed By	Reference
APRAC	SRI international	B-11, B-12, B-13
Simplified Street Canyon Model	Los Alamos Scientific Laboratory	B-14
Rigorous Solution to Navier-Stokes Equation	Los Alamos Scientific Laboratory	B-14
"Air Pollution Model for Street Level Air"	University of Wisconsin	B-15
"Air Pollution Patterns in an Urban Street Canyon"	Vanderbilt University	B-16
"Microscale Air Pollution Model"	Environmental Systems Laboratory	B-17

Table B-3. Mathematical Dispersion Models Examined, Other Urban Sites

Model	Developed By	Reference
"Air Quality Modeling at Signalized Intersections"	GCA/Technology Division	B-18

Table B-4. Mathematical Dispersion Models Examined, Urban Areawide

Model	Developed By	Reference
Air Quality Display Model	TRW Systems Group	B-19
Climatological Dispersion Model	U. S. Environmental Protection Agency	B-20
Gifford-Hanna Models	National Oceanic and Atmospheric Administration	B-20
"A Simple Method of Calculating Dispersion from Urban Area Sources"	National Oceanic and Atmospheric Adminiatration	B-21
SAPOLLUT	U. S. Department of Transportation, Federal Highway Administration	B-22

Table B-5. Measured Data Bases Examined, Urban Freeway

Location	Performed By	Reference
GM Proving Ground, Milford, Michigan	General Motors	B-23
Santa Clara, California	SRI International	B-24, B-25
San Jose, California	SRI International	B-25
Chicago, Illinois (2 locations)	Argonne National Laboratory	B-26
Virginia (5 locations)	Virginia Highway and Transportation Research Council	B-27
Los Angeles (several locations)	California Department of Transportation	B-28, B-29
Los Angeles	U. S. Environmental Protection Agency	B-30
Nashville, Tennessee (3 locations)	University of Tennessee	B-31
Winston-Salem, North Carolina (several locations)	K. E. Knoll	B-32
St. Louis, Missouri	SRI International	B-13
Texas (several locations)-detailed data not yet available	Texas State Department of Highways and Public Transportation	B-33
Long Island, New York (detailed data not yet available)	New York State Department of Environmental Conservation	B-34
Chicago, Illinois (detailed data not yet available)	Illinois Environmental Protection Agency	B-35

Table B-6. Measured Data Bases Examined, Street Canyon

Location	Performed By	Reference
St. Louis, Missouri	SRI International	B-13, B-36
San Jose, California	SRI International	B-12, B-37
Nashville, Tennessee	Vanderbilt University	B-38
New York City	Environmental Systems Laboratory	B-17

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APPENDIX C

PROJECTION OF URBAN STREET CANYON PARTICULATE CONCENTRATIONS USING AMBIENT CO MEASUREMENTS DATA

The analysis of particulate effects for the urban street canyon relies in part upon long-term CO measurements data taken at fixed probe locations in the urban area. A simple proportional relationship using these data is used to estimate particulate concentrations for future projection years. The development of this relationship is described in the following paragraphs.

Using subscripts 1 and 2 to denote base year measured conditions and projected conditions, respectively, the total mass of CO released by traffic in the street canyon may be written as

$$m_{CO_1} = \left(EF_{CO}\right)_1 \times TC_1 \times T_1 \times f(L) \tag{1}$$

where m is in grams, EF is the traffic-composite emission factor in g/mi, TC is the traffic count in vehicles per hour, L is the length of the street canyon, and T is a characteristic averaging time (a one-hour average is typical for ambient CO measurements).

The relationship between moles of CO generated by traffic and the resultant molal distribution of CO in the air is governed by some functional relationship ϕ such that

$$\left(X_{CO}\right)_1 = \phi_1 \times N_{CO_1} = \phi_1 \times \frac{m_{CO}}{MW_{CO}} \tag{2}$$

where

X_{CO} = mole fraction CO in ambient air at the specified measuring point

ϕ = functional relationship

N_{CO} = moles of CO generated by traffic

MW_{CO} = molecular weight of CO = 28

The functional relationship ϕ incorporates all site-specific geometrical aspects of the street canyon, and all meteorological aspects. This relationship will remain undefined, except for the assumption that it is a proportional one; that is, doubling the number of moles of CO released into the street canyon doubles the ambient air CO concentration measured at a specific point in the street canyon for fixed meteorological conditions.

Combining equations (1) and (2),

$$\left(X_{CO}\right)_1 = \frac{EF_{CO_1}}{MW_{CO}} \times TC_1 \times T_1 \times \phi_1 \times f(L) \tag{3}$$

Under the assumption that particulates behave as a gas, an analogous equation may be written for particulates (P). Then,

$$\frac{\left(X_P\right)_2}{\left(X_{CO}\right)_1} = \frac{\left(EF_P\right)_2}{\left(EF_{CO}\right)_1} \times \frac{MW_{CO}}{MW_P} \times \frac{TC_2}{TC_1} \times \frac{\phi_2}{\phi_1} \tag{4}$$

It is assumed that a long-term average CO concentration $\left(X_{CO}\right)_1$ may be selected as representative of street canyon effects. For the same traffic and micrometeorological conditions, the functional relationship ϕ is assumed to remain unchanged between the baseline and projection cases; i.e., $\phi_1 = \phi_2$. Then, converting mole fraction particulates to the desired units of micrograms per cubic meter of ambient air, using the factor 22.4 liters/g mole,

$$\frac{\mu g P}{m^3 \text{ air}} = \left(X_P\right)_2 \times MW_P \times 10^6 \times \frac{1}{22.4} \times \frac{T_o}{T} \times \frac{P}{P_o} \times \frac{1}{10^3} \times 10^6 \tag{5}$$

Substituting (5) into (4), and expressing CO in the measured units of ppm ($ppm_{CO} = X_{CO} \times 10^6$),

$$\frac{\left(\mu gP/m^3\right)_2}{\left(ppm_{CO}\right)_1} = \frac{\left(EF_P\right)_2}{\left(EF_{CO}\right)_1} \times \frac{TC_2}{TC_1} \times \frac{T_o}{T} \times \frac{p}{p_o} \times 1.25 \times 10^3 \tag{6}$$

Concentrations expressed in $\mu g/m^3$ are typically reported at 25°C (298°K). Taking $p = p_o = 1$ atm, and $T_o = 0°C$ (273°K),

$$\left[\frac{\left(\mu gP/m^3\right)_2}{\left(ppm_{CO}\right)_1}\right] = \left[\frac{\left(EF_P\right)_2}{\left(EF_{CO}\right)_1}\right] \times \frac{\left(TC_2\right)}{\left(TC_1\right)} \times 1.145 \times 10^3 \tag{7}$$

In Manhattan, historical saturation traffic conditions were assumed to continue unchanged for the projection years, so that $TC_2 = TC_1$. The 50th-percentile value of long-term CO concentration measurements was used for the term $\left(ppm_{CO}\right)_1$ as representative of frequently encountered conditions. Higher percentile values were used for special analyses described in the report.

APPENDIX D

REGIONAL AREA POLLUTANT DUMPS

Pollutant dump quantities developed in the areawide urban analysis are presented in Tables D-1 through D-10 for Manhattan, Tables D-11 through D-20 for St. Louis, and Tables D-21 through D-30 for Phoenix. Each table provides results for one dieselization scenario/projection year case. Values are given for HC, CO, NO_x, and particulates in tons/yr and for BaP in lbs/yr. Contributions are identified for gasoline, diesel, and total vehicle sources. A double entry is shown for diesel BaP, representing dump results corresponding to low/high estimates of diesel vehicle BaP emission rate. Stationary source dumps are listed by point, area, and total source contributions. No entries for BaP are provided under stationary sources; these quantities could not be determined on a regional basis.

Table D-1. Manhattan Pollutant Dump, Tons/Yr, Base Case 1975

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	17,545.0	144,640.2	8,761.5	548.2	491.1	----	1,039.3	4.4
LDT	910.7	6,582.2	382.9	22.1	18.5	----	40.6	0.2
HDV	4,469.6	42,292.0	1,820.4	146.8	48.9	----	195.7	1.0
Sub-Total Gasoline	22,925.3	193,514.4	10,964.8	717.1	558.5	----	1,275.6	5.6
Diesel								
LDV	1.5	4.6	4.1	1.6	0.6	----	2.2	0.005/0.03
LDT	0.1	0.1	0.1	0.04	0.01	----	0.05	---
HDV	252.9	1,937.2	1,224.3	116.4	29.1	----	145.5	0.5/2.9
Sub-Total Diesel	254.5	1,941.9	1,228.5	118.0	29.7	----	147.7	0.5/2.9
Sub-Total Mobile	23,179.8	195,456.3	12,193.3	835.1	588.2	----	1,423.3	6.1/8.5
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	25,131.8	204,244.3	50,874.3	11,903.1	588.2	8,316.0	20,807.3	**

*Lbs/yr; **Indeterminate

Table D-2. Manhattan Pollutant Dump, Tons/Yr, Base Case 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	4,658.5	43,288.6	3,721.9	49.2	487.1	----	536.3	0.7
LDT	459.3	4,623.7	244.6	11.0	18.5	----	29.5	0.09
HDV	1,633.0	23,305.6	1,201.1	119.9	40.0	----	159.9	0.8
Sub-Total Gasoline	6,750.8	71,217.9	5,167.6	180.1	545.6	----	725.7	1.6
Diesel								
LDV	9.9	38.4	33.9	12.1	4.6	----	16.7	0.05/0.3
LDT	0.1	0.3	0.3	0.09	0.04	----	0.1	----
HDV	334.0	2,418.0	1,628.3	176.1	44.0	----	220.1	0.8/4.3
Sub-Total Diesel	344.0	2,456.7	1,662.5	188.3	48.6	----	236.9	0.9/4.6
Sub-Total Mobile	7,094.8	73,674.6	6,830.1	368.4	594.2	----	962.6	2.5/6.2
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	9,046.8	82,462.6	45,511.1	11,436.4	594.2	8,316.0	20,346.6	**

*Lbs/yr; **Indeterminate

Table D-3. Manhattan Pollutant Dump, Tons/Yr, Base Case 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	3,458.9	29,730.9	3,286.8	27.9	486.8	----	514.7	0.5
LDT	306.9	2,995.3	182.6	4.8	18.5	----	23.3	0.05
HDV	917.0	10,283.9	628.6	85.4	28.5	----	113.9	0.6
Sub-Total Gasoline	4,682.8	43,010.1	4,098.0	118.1	533.8	----	651.9	1.2
Diesel								
LDV	10.0	41.4	27.5	7.9	4.9	----	12.8	0.05/0.3
LDT	0.1	0.3	0.3	0.06	0.04	----	0.1	----
HDV	394.5	3,420.8	1,083.9	252.7	63.2	----	315.9	1.2/6.2
Sub-Total Diesel	404.6	3,462.5	1,111.7	260.7	68.1	----	328.8	1.3/6.5
Sub-Total Mobile	5,087.4	46,472.6	5,209.7	378.8	601.9	----	980.7	2.5/7.7
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	7,039.4	55,260.6	43,890.7	11,446.8	601.9	8,316.0	20,364.7	**

*Lbs/yr; **Indeterminate

Table D-4. Manhattan Pollutant Dump, Tons/Yr, Base Case 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	3,335.9	26,564.6	3,264.6	25.6	486.8	----	512.4	0.5
LDT	186.0	1,707.0	172.7	1.2	18.5	----	19.7	0.02
HDV	197.5	1,960.8	138.9	19.9	6.6	----	26.5	0.1
Sub-Total Gasoline	3,719.4	30,232.4	3,576.2	46.7	511.9	----	558.6	0.6
Diesel								
LDV	10.0	41.4	24.3	6.1	4.9	----	11.0	0.05/0.3
LDT	0.1	0.3	0.3	0.05	0.04	----	0.1	----
HDV	569.2	5,377.3	1,091.6	398.2	99.6	----	497.8	1.8/9.8
Sub-Total Diesel	579.3	5,419.0	1,116.2	404.4	104.5	----	508.9	1.9/10.1
Sub-Total Mobile	4,298.7	35,651.4	4,692.4	451.1	616.4	----	1,067.5	2.5/10.7
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	6,250.7	44,439.4	43,373.4	11,519.1	616.4	8,316.0	20,451.5	**

*Lbs/yr; **Indeterminate

Table D-5. Manhattan Pollutant Dump, Tons/Yr, 10-Percent Dieselization Rate, 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	4,582.3	42,701.0	3,648.1	49.2	466.8	----	516.0	0.6
LDT	455.0	4,578.8	253.8	10.6	17.9	----	28.5	0.09
HDV	1,633.0	23,305.6	1,201.1	119.9	40.0	----	159.9	0.8
Sub-Total Gasoline	6,670.3	70,585.4	5,103.0	179.7	524.7	----	704.4	1.5
Diesel								
LDV	51.7	211.0	164.7	60.2	24.8	----	85.0	0.25/1.5
LDT	2.5	5.3	5.0	1.6	0.6	----	2.2	0.006/0.04
HDV	334.0	2,418.0	1,628.3	176.1	44.0	----	220.1	0.8/4.3
Sub-Total Diesel	388.2	2,634.3	1,798.0	237.9	69.4	----	307.3	1.1/5.8
Sub-Total Mobile	7,058.5	73,219.7	6,901.0	417.6	594.1	----	1,011.7	2.6/7.3
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1, 544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	9,010.5	82,007.7	45,582.0	11,485.6	594.1	8,316.0	20,395.7	**

*Lbs/yr; **Indeterminate

Table D-6. Manhattan Pollutant Dump, Tons/Yr, 10-Percent Dieselization Rate, 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	3,227.8	27,924.1	3,060.6	27.0	447.8	----	474.8	0.5
LDT	286.0	2,894.0	172.4	4.6	17.1	----	21.7	0.04
HDV	917.0	10,283.9	628.6	85.4	28.5	----	113.9	0.6
Sub-Total Gasoline	4,430.8	41,102.0	3,861.6	117.0	493.4	----	610.4	1.1
Diesel								
LDV	89.9	372.8	231.8	64.2	43.9	----	108.1	0.4/2.6
LDT	5.5	11.7	10.0	2.1	1.4	----	3.5	0.01/0.06
HDV	394.5	3,420.8	1,083.9	252.7	63.2	----	315.9	1.2/6.2
Sub-Total Diesel	489.9	3,805.3	1,325.7	319.0	108.5	----	427.5	1.6/8.9
Sub-Total Mobile	4,920.7	44,907.3	5,187.3	436.0	601.9	----	1,037.9	2.7/10.0
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	6,872.7	53,695.3	43,868.3	11,504.0	601.9	8,316.0	20,421.9	**

*Lbs/yr; **Indeterminate

Table D-7. Manhattan Pollutant Dump, Tons/Yr, 10-Percent Dieselization Rate, 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	3,038.5	24,160.4	2,974.6	23.4	442.5	----	465.9	0.4
LDT	172.5	1,544.3	155.5	1.1	16.7	----	17.8	0.02
HDV	197.5	1,960.8	138.9	19.9	6.6	----	26.5	0.1
Sub-Total Gasoline	3,408.5	27,665.5	3,269.0	44.4	465.8	----	510.2	0.5
Diesel								
LDV	100.7	417.5	245.6	61.4	49.2	----	110.6	0.5/2.9
LDT	7.2	15.3	12.6	2.3	1.8	----	4.1	0.02/0.1
HDV	569.2	5,377.3	1,091.6	398.2	99.6	----	497.8	1.8/9.8
Sub-Total Diesel	677.1	5,810.1	1,349.8	461.9	150.6	----	612.5	2.3/12.8
Sub-Total Mobile	4,085.6	33,475.6	4,618.8	506.3	616.4	----	1,122.7	2.8/13.3
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	6,037.6	42,263.6	43,299.8	11,574.3	616.4	8,316.0	20,506.7	**

*Lbs/yr; **Indeterminate

Table D-8. Manhattan Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 1985

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	4,356.0	41,491.5	3,495.7	46.7	430.6	----	477.3	0.6
LDT	447.4	4,494.4	232.7	10.6	16.9	----	27.5	0.09
HDV	1,633.0	23,305.6	1,201.1	119.9	40.0	----	159.9	0.8
Sub-Total Gasoline	6,436.4	69,291.5	4,929.5	177.2	487.5	----	664.7	1.5
Diesel								
LDV	125.4	519.1	405.6	146.5	61.1	----	207.6	0.6/3.7
LDT	6.3	13.3	12.7	4.1	1.6	----	5.7	0.02/0.09
HDV	334.0	2,418.0	1,628.3	176.1	44.0	----	220.1	0.8/4.3
Sub-Total Diesel	465.7	2,950.4	2,046.6	326.7	106.7	----	433.4	1.4/8.1
Sub-Total Mobile	6,902.1	72,241.9	6,976.1	503.9	594.2	----	1,098.1	2.9/9.6
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	8,854.1	81,029.9	45,657.1	11,571.9	594.2	8,316.0	20,482.1	**

*Lbs/yr; **Indeterminate

Table D-9. Manhattan Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	2,836.9	24,787.2	2,677.1	19.7	382.2	----	401.9	0.4
LDT	268.2	2,731.8	156.6	4.5	15.0	----	19.5	0.04
HDV	917.0	10,283.9	628.6	85.4	28.5	----	113.9	0.6
Sub-Total Gasoline	4,022.1	37,802.9	3,462.3	109.6	425.7	----	535.3	1.0
Diesel								
LDV	223.7	930.3	579.2	159.5	109.5	----	269.0	1.1/6.6
LDT	13.8	29.3	25.0	5.4	3.5	----	8.9	0.03/0.21
HDV	394.5	3,420.8	1,083.9	252.7	63.2	----	315.9	1.2/6.2
Sub-Total Diesel	632.0	4,380.4	1,688.1	417.6	176.2	----	593.8	2.3/13.0
Sub-Total Mobile	4,654.1	42,183.3	5,150.4	527.2	601.9	----	1,129.1	3.3/14.0
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	6,606.1	50,971.3	43,831.4	11,595.2	601.9	8,316.0	20,513.1	**

*Lbs/yr; **Indeterminate

Table D-10. Manhattan Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 2000

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	2,536.0	20,168.1	2,478.0	19.4	372.2	----	391.6	0.4
LDT	145.9	1,312.3	130.6	1.0	14.0	----	15.0	0.01
HDV	197.5	1,960.8	138.9	19.9	6.6	----	26.5	0.1
Sub-Total Gasoline	2,879.4	23,441.2	2,747.5	40.3	392.8	----	433.1	0.5
Diesel								
LDV	251.3	1,041.9	613.6	152.4	119.5	----	271.9	1.2/7.4
LDT	18.0	38.2	31.6	5.8	4.5	----	10.3	0.04/0.3
HDV	569.2	5,377.3	1,091.6	398.2	99.6	----	497.8	1.8/9.8
Sub-Total Diesel	838.5	6,457.4	1,736.8	556.4	223.6	----	780.0	3.0/17.5
Sub-Total Mobile	3,717.9	29,898.6	4,484.3	596.7	616.4	----	1,213.1	3.5/18.0
STATIONARY								
Point Sources	408.0	5,138.0	17,115.0	2,931.0	----	----	2,931.0	**
Area Sources	1,544.0	3,650.0	21,566.0	8,137.0	----	8,316.0	16,453.0	**
Sub-Total Stationary	1,952.0	8,788.0	38,681.0	11,068.0	----	8,316.0	19,384.0	**
Total	5,669.9	38,686.6	43,165.3	11,664.7	616.4	8,316.0	20,597.1	**

*Lbs/Yr; **Indeterminate

Table D-11. St. Louis Pollutant Dump, Tons/Yr, Base Case 1975

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	91,217.4	748,442.5	43,493.9	2,698.3	2,394.0	----------	5,092.3	21.7
LDT	15,780.0	120,311.0	7,713.7	444.6	375.5	----------	820.1	3.6
HDV	26,411.5	249,907.3	10,757.0	867.3	289.1	----------	1,156.4	5.8
Sub-Total Gasoline	133,408.9	1,118,660.8	64,964.6	4,010.2	3,058.6	----------	7,068.8	31.1
Diesel								
LDV	6.5	20.4	18.0	7.2	2.4	----------	9.6	0.02/0.14
LDT	1.0	2.2	2.3	1.0	0.3	----------	1.3	0.003/0.02
HDV	1,498.0	11,291.0	7,234.3	687.8	172.0	----------	859.8	3.2/16.9
Sub-Total Diesel	1,505.5	11,313.6	7,254.6	696.0	174.7	----------	870.7	3.2/17.1
Sub-Total Mobile	134,914.4	1,129,974.4	72,219.2	4,706.2	3,233.3	----------	7,939.5	34.3/48.2
STATIONARY								
Point Sources	48,403.0	164,218.0	313,812.0	44,538.0	------	---------	44,538.0	**
Area Sources	44,827.0	166,500.0	53,214.0	9,437.0	------	1,246,663.0	1,256,100.0	**
Sub-Total Stationary	93,230.0	330,718.0	367,026.0	53,975.0	------	1,246,663.0	1,300,638.0	**
Total	228,144.4	1,460,692.4	439,245.2	58,681.2	3,233.3	1,246,663.0	1,308,577.5	**

*Lbs/yr; **Indetermirate

Table D-12. St. Louis Pollutant Dump, Tons/Yr, Base Case 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	29,040.4	273,429.0	21,845.2	333.3	2,574.2	----------	2,907.5	4.1
LDT	7,319.0	78,456.4	5,121.7	193.7	406.4	----------	600.1	1.6
HDV	10,451.0	149,155.9	7,686.9	767.3	255.8	----------	1,023.1	5.1
Sub-Total Gasoline	46,810.4	501,041.3	34,653.8	1,294.3	3,236.4	----------	4,530.7	10.8
Diesel								
LDV	52.1	198.7	166.2	63.8	23.4	----------	87.2	0.2/1.4
LDT	3.0	6.4	6.2	2.1	0.7	----------	2.8	0.008/0.05
HDV	2,116.0	15,365.0	10,421.1	1,127.3	281.8	----------	1,409.1	5.2/27.7
Sub-Total Diesel	2,171.1	15,570.1	10,593.5	1,193.2	305.9	----------	1,499.1	5.4/29.1
Sub-Total Mobile	48,981.5	516,611.4	45,247.3	2,487.5	3,542.3	----------	6,029.8	16.2/39.9
STATIONARY								
Point Sources	52,662.0	178,669.0	341,827.0	48,457.0	-----	----------	48,457.0	**
Area Sources	48,772.0	181,152.0	57,897.0	10,267.0	-----	1,201,050.0	1,211,317.0	**
Sub-Total Stationary	101,434.0	359,821.0	399,724.0	58,724.0	-----	1,201,050.0	1,259,774.0	**
Total	150,415.5	876,432.4	444,971.3	61,211.5	3,542.3	1,201,050.0	1,265,803.8	**

*Lbs/yr; **Indeterminate

Table D-13. St. Louis Pollutant Dump, Tons/Yr, Base Case 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	21,832.2	192,829.4	20,100.9	172.0	2,683.1	----------	2,855.1	2.9
LDT	4,557.1	45,654.9	3,492.9	63.9	424.0	----------	487.9	0.7
HDV	6,118.6	68,621.7	4,194.2	570.1	190.0	----------	760.1	3.8
Sub-Total Gasoline	32,507.9	307,106.0	27,788.0	806.0	3,297.1	----------	4,103.1	7.4
Diesel								
LDV	54.4	223.4	147.7	44.2	26.3	----------	70.5	0.3/1.6
LDT	3.4	7.2	6.2	1.4	0.8	----------	2.2	0.008/0.05
HDV	2,552.2	22,799.3	7,232.4	1,686.3	421.6	----------	2,107.9	7.8/41.5
Sub-Total Diesel	2,610.0	23,029.9	7,386.3	1,731.9	448.7	----------	2,180.6	8.1/43.1
Sub-Total Mobile	35,117.9	330,135.9	35,174.3	2,537.9	3,745.8	----------	6,283.7	15.5/50.5
STATIONARY								
Point Sources	55,034.0	186,716.0	356,804.0	50,640.0	-----	----------	50,640.0	**
Area Sources	50,968.0	189,311.0	60,504.0	10,730.0	-----	1,181,329.0	1,192,059.0	**
Sub-Total Stationary	106,002.0	376,027.0	417,308.0	61,370.0	-----	1,181,329.0	1,242,699.0	**
Total	141,119.9	706,162.9	452,482.3	63,907.9	3,745.8	1,181,329.0	1,248,982.7	**

*Lbs/yr; **Indeterminate

Table D-14. St. Louis Pollutant Dump, Tons/Yr, Base Case 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	22,454.0	180,031.4	21,895.4	154.7	2,947.4	-----------	3,102.1	2.9
LDT	3,735.4	34,382.0	3,697.2	25.0	465.8	-----------	490.8	0.5
HDV	1,450.9	14,403.1	1,020.5	146.3	48.8	-----------	195.1	1.0
Sub-Total Gasoline	27,640.3	228,816.5	26,613.1	326.0	3,462.0	-----------	3,788.0	4.4
Diesel								
LDV	59.8	247.9	145.9	36.5	29.2	-----------	65.7	0.3/1.7
LDT	3.7	8.0	6.5	1.2	0.9	-----------	2.1	0.009/0.06
HDV	4,176.6	39,498.9	8,018.3	2,925.8	731.5	-----------	3,657.3	13.5/72.0
Sub-Total Diesel	4,240.1	39,754.7	8,170.7	2,963.5	761.6	-----------	3,725.1	13.8/73.8
Sub-Total Mobile	31,880.4	268,571.2	34,783.8	3,289.5	4,223.6	-----------	7,513.1	18.2/78.2
STATIONARY								
Point Sources	60,359.0	204,780.0	391,323.0	55,539.0	------	-----------	55,539.0	**
Area Sources	54,510.0	202,464.0	64,671.0	11,475.0	------	1,147,111.0	1,158,586.0	**
Sub-Total Stationary	114,869.0	407,244.0	455,994.0	67,014.0	------	1,147,111.0	1,214,125.0	**
Total	146,749.4	675,815.2	490,777.8	70,303.5	4,223.6	1,147,111.0	1,221,638.1	**

*Lbs/yr; **Indeterminate

Table D-15. St. Louis Pollutant Dump, Tons/Yr, 10-Percent Dieselization, 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	28,813.1	271,774.4	21,541.3	329.8	2,482.5	-----------	2,812.3	4.0
LDT	7,247.0	77,536.2	4,533.5	191.0	389.7	-----------	580.7	1.6
HDV	10,451.0	149,155.9	7,686.9	767.3	255.8	-----------	1,023.1	5.1
Sub-Total Gasoline	46,511.1	498,466.5	33,761.7	1,288.1	3,128.0	-----------	4,416.1	10.7
Diesel								
LDV	240.5	978.1	773.4	282.5	115.1	-----------	397.6	1.1/6.9
LDT	69.8	148.2	136.7	49.0	17.4	-----------	66.4	0.2/1.1
HDV	2,116.0	15,365.0	10,421.1	1,127.3	281.8	-----------	1,409.1	5.2/27.7
Sub-Total Diesel	2,426.3	16,491.3	11,331.2	1,458.8	414.3	-----------	1,873.1	6.5/35.7
Sub-Total Mobile	48,937.4	514,957.8	45,092.9	2,746.9	3,542.3	-----------	6,289.2	17.2/46.4
STATIONARY								
Point Sources	52,662.0	178,669.0	341,827.0	48,457.0	-----	-----------	48,457.0	**
Area Sources	48,772.0	181,152.0	57,897.0	10,267.0	-----	1,201,050.0	1,211,317.0	**
Sub-Total Stationary	101,434.0	359,821.0	399,724.0	58,724.0	-----	1,201,050.0	1,259,774.0	**
Total	150,371.4	874,778.8	444,816.9	61,470.9	3,542.3	1,201,050.0	1,266,063.2	**

*Lbs/yr; **Indeterminate

Table D-16. St. Louis Pollutant Dump, Tons/Yr, 10-Percent Dieselization, 1990

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	20,560.1	182,831.8	18,823.4	159.9	2,476.4	-----------	2,636.3	2.7
LDT	4,288.9	43,172.6	3,247.2	61.0	388.4	-----------	449.4	0.4
HDV	6,118.6	68,621.7	4,194.2	570.1	190.0	-----------	760.1	3.8
Sub-Total Gasoline	30,967.6	294,626.1	26,264.8	791.0	3,054.8	-----------	3,845.8	6.9
Diesel								
LDV	478.2	1,980.6	1,249.7	350.6	233.0	-----------	583.6	2.3/14.0
LDT	150.8	309.6	262.2	54.5	36.4	-----------	90.9	0.4/2.2
HDV	2,552.2	22,799.3	7,232.4	1,686.3	421.6	-----------	2,107.9	7.8/41.5
Sub-Total Diesel	3,181.2	25,089.5	8,744.3	2,091.4	691.0	-----------	2,782.4	10.5/57.7
Sub-Total Mobile	34,148.8	319,715.6	35,009.1	2,882.4	3,745.8	-----------	6,628.2	17.4/64.6
STATIONARY								
Point Sources	55,034.0	186,716.0	356,804.0	50,640.0	-----	-----------	50,640.0	**
Area Sources	50,968.0	189,311.0	60,504.0	10,730.0	-----	1,181,329.0	1,192,059.0	**
Sub-Total Stationary	106,002.0	376,027.0	417,308.0	61,370.0	-----	1,181,329.0	1,242,699.0	**
Total	140,150.8	695,742.6	452,317.1	64,252.4	3,745.8	1,181,329.0	1,249,327.2	**

*Lbs/yr; **Indeterminate

Table D-17. St. Louis Pollutant Dump, Tons/Yr, 10-Percent Dieselization, 2000

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	20,400.4	163,679.8	19,905.6	140.7	2,679.8	-----------	2,820.5	2.7
LDT	3,580.5	31,057.5	3,337.0	22.3	420.2	-----------	442.5	0.4
HDV	1,450.9	14,403.1	1,020.5	146.3	48.8	-----------	195.1	1.0
Sub-Total Gasoline	25,431.8	209,140.4	24,263.1	309.3	3,148.8	-----------	3,458.1	4.1
Diesel								
LDV	608.4	2,522.5	1,486.0	373.0	296.8	-----------	669.8	3.0/17.8
LDT	186.1	395.5	325.9	58.4	46.5	-----------	104.9	0.5/2.8
HDV	4,176.6	39,498.9	8,018.3	2,925.8	731.5	-----------	3,657.3	13.5/72.0
Sub-Total Diesel	4,971.1	42,416.9	9.830.2	3,357.2	1,074.8	-----------	4,432.0	17.0/92.6
Sub-Total Mobile	30,402.9	251,557.3	34,093.3	3,666.5	4,223.6	-----------	7,890.1	21.1/96.7
STATIONARY								
Point Sources	60,359.0	204,780.0	391,323.0	55,539.0	-----	-----------	55,539.0	**
Area Sources	54,510.0	202,464.0	64,671.0	11,475.0	-----	1,147,111.0	1,158,586.0	**
Sub-Total Stationary	114,869.0	407,244.0	455,994.0	67,014.0	-----	1,147,111.0	1,214,125.0	**
Total	145,271.9	658,801.3	490,087.3	70,680.5	4,223.6	1,147,111.0	1,222,015.1	**

*Lbs / yr; **Indeterminate

Table D-18. St. Louis Pollutant Dump, Tons/Yr, 25-Percent Dieselization, 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	28,087.6	266,188.4	20,819.2	322.1	2,316.7	----------	2,638.8	3.8
LDT	7,019.1	75,321.5	4,308.4	194.0	363.0	----------	557.0	1.5
HDV	10,451.0	149,155.9	7,686.9	767.3	255.8	----------	1,023.1	5.1
Sub-Total Gasoline	45,557.7	490,665.8	32,814.5	1,283.4	2,935.5	----------	4,218.9	10.4
Diesel								
LDV	581.7	2,386.7	1,885.8	687.0	280.8	----------	967.8	2.8/16.8
LDT	176.9	375.8	352.8	108.8	44.2	----------	153.0	0.4/2.7
HDV	2,116.0	15,365.0	10,421.1	1,127.3	281.9	----------	1,409.2	5.2/27.7
Sub-Total Diesel	2,874.6	18,127.5	12,659.7	1,923.1	606.9	----------	2,530.0	8.4/47.2
Sub-Total Mobile	48,432.3	508,793.3	45,474.2	3,206.5	3,542.4	----------	6,748.9	18.8/57.6
STATIONARY								
Point Sources	52,662.0	178,669.0	341,827.0	48,457.0	-----	----------	48,457.0	**
Area Sources	48,772.0	181,152.0	57,897.0	10,267.0	-----	1,201,050.0	1,211,317.0	**
Sub-Total Stationary	101,434.0	359,821.0	399,724.0	58,724.0	-----	1,201,050.0	1,259,774.0	**
Total	149,866.3	868,614.3	445,198.2	61,930.5	3,542.4	1,201,050.0	1,266,522.9	**

*Lbs/yr; **Indeterminate

Table D-19. St. Louis Pollutant Dump, Tons/Yr, 25-Percent Dieselization, 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	18,228.7	164,028.7	16,582.8	143.6	2,125.5	----------	2,269.1	2.4
LDT	3,858.5	39,267.7	2,857.8	57.2	333.7	----------	390.9	0.6
HDV	6,118.6	68,621.7	4,194.2	570.1	190.0	----------	760.1	3.8
Sub-Total Gasoline	28,205.8	271,918.1	23,634.8	770.9	2,649.2	----------	3,420.1	6.8
Diesel								
LDV	1,193.3	4,962.9	3,118.5	874.3	583.9	----------	1,458.2	5.8/35.0
LDT	364.5	774.5	656.3	136.6	91.2	----------	227.8	0.9/5.4
HDV	2,552.2	22,799.3	7,232.4	1,686.3	421.6	----------	2,107.9	7.8/41.5
Sub-Total Diesel	4,110.0	28,536.7	11,007.2	2,697.2	1,096.7	----------	3,793.9	14.5/81.9
Sub-Total Mobile	32,315.8	300,454.8	34,642.0	3,468.1	3,745.9	----------	7,214.0	21.3/88.7
STATIONARY								
Point Sources	55,034.0	186,716.0	356,804.0	50,640.0	-----	----------	50,640.0	**
Area Sources	50,968.0	189,311.0	60,504.0	10,730.0	-----	1,181,329.0	1,192.059.0	**
Sub-Total Stationary	106,002.0	376,027.0	417,308.0	61,370.0	-----	1,181,329.0	1,242,699.0	**
Total	138,317.8	676,481.8	451,950.0	64,838.1	3,745.9	1,181,329.0	1,249,913.0	**

*Lbs/yr; **Indeterminant

Table D-20. St. Louis Pollutant Dump, Tons/Yr, 25-Percent Dieselization, 2000

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	17,040.6	136,611.2	16,598.7	117.3	2,234.2	---------	2,351.5	2.2
LDT	2,990.9	25,967.5	2,841.6	18.7	350.4	---------	369.1	0.4
HDV	1,450.9	14,403.1	1,020.5	146.3	48.8	---------	195.1	1.0
Sub-Total Gasoline	21,482.4	176,981.8	20,460.8	282.3	2,633.4	---------	2,915.7	3.6
Diesel								
LDV	1,521.8	6,310.0	3,715.5	932.0	742.3	---------	1,674.3	7.4/44.5
LDT	465.3	988.9	817.5	148.3	116.3	---------	264.6	1.2/7.0
HDV	4,176.6	39,498.9	8,018.3	2,925.8	731.5	---------	3,657.3	13.5/72.0
Sub-Total Diesel	6,163.7	46,797.8	12,551.3	4,006.1	1,590.1	---------	5,596.2	22.1/123.5
Sub-Total Mobile	27,646.1	223,779.6	33,012.1	4,288.4	4,223.5	---------	8,511.9	25.7/127.1
STATIONARY								
Point Sources	60,359.0	204,780.0	391,323.0	55,539.0	-----	---------	55,539.0	**
Area Sources	54,510.0	202,464.0	64,671.0	11,475.0	-----	1,147,111.0	1,158,586.0	**
Sub-Total Stationary	114,869.0	407,244.0	455,994.0	67,014.0	-----	1,147,111.0	1,214,125.0	**
Total	142,515.1	631,023.6	489,006.1	71,302.4	4,223.5	1,147,111.0	1,222,636.9	**

*Lbs/yr; **Indeterminate

Table D-21. Phoenix Pollutant Dump, Tons/Yr, Base Case 1975

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	45,469.0	365,977.1	19,999.6	1,261.8	1,082.5	-------	2,344.3	10.1
LDT	12,940.1	93,195.9	5,981.8	327.7	269.5	-------	597.2	2.6
HDV	13,232.0	92,981.9	3,971.8	320.2	106.7	-------	426.9	2.1
Sub-Total Gasoline	71,641.1	552,154.9	29,953.2	1,909.7	1,458.7	-------	3,368.4	14.8
Diesel								
LDV	2.2	7.6	6.5	2.7	0.6	-------	3.3	-----
LDT	0.2	0.5	0.5	0.2	0.1	-------	0.3	0.001/0.004
HDV	551.7	4,226.6	2,681.0	254.0	63.5	-------	317.5	1.2/6.2
Sub-Total Diesel	554.1	4,234.7	2,688.0	256.9	64.2	-------	321.1	1.2/6.2
Sub-Total Mobile	72,195.2	556,389.6	32,641.2	2,166.6	1,522.9	-------	3,689.5	16.0/21.0
STATIONARY								
Point Sources	4,922.0	282.0	7,820.0	7,957.0	-----	-------	7,957.0	**
Area Sources	34,221.0	13,841.0	8,254.0	657.0	-----	649,225.0	649,882.0	**
Sub-Total Stationary	39,143.0	14,123.0	16,074.0	8,614.0	-----	649,225.0	657,839.0	**
Total	111,338.2	570,512.6	48,715.2	10,780.6	1,522.9	649,225.0	661,528.5	**

*Lbs/yr; **Indeterminate

Table D-22. Phoenix Pollutant Dump, Tons/Yr, Base Case 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	22,550.5	213,880.1	15,248.4	289.8	1,597.3	-------	1,887.1	3.2
LDT	8,859.4	90,689.9	5,044.6	218.7	399.9	-------	618.6	1.8
HDV	4,839.5	69,069.3	3,559.6	355.3	118.4	-------	473.7	2.4
Sub-Total Gasoline	36,249.4	373,639.3	23,852.6	863.8	2,115.6	-------	2,979.4	7.4
Diesel								
LDV	31.4	120.8	96.6	33.8	12.9	-------	46.7	0.12/0.73
LDT	2.2	4.7	4.4	1.5	0.8	-------	2.3	0.005/0.033
HDV	989.8	7,165.9	4,920.2	522.0	130.5	-------	652.5	2.4/12.8
Sub-Total Diesel	1,023.4	7,291.4	5,021.2	557.3	144.2	-------	701.5	2.5/13.6
Sub-Total Mobile	37,272.8	380,930.7	28,873.8	1,421.1	2,259.8	-------	3,680.9	9.9/21.0
STATIONARY								
Point Sources	4,911.0	260.0	7,061.0	11,242.0	-----	-------	11,242.0	**
Area Sources	28,958.0	15,587.0	9,127.0	949.0	-----	636,085.0	637,034.0	**
Sub-Total Stationary	33,869.0	15,847.0	16,188.0	12,191.0	-----	636,085.0	648,276.0	**
Total	71,141.8	396,777.7	45,061.8	13,612.1	2,259.8	636,085.0	651,956.9	**

*Lbs/yr; **Indeterminate

Table D-23. Phoenix Pollutant Dump, Tons/Yr, Base Case 1990

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	17,255.4	162,529.0	15,436.1	139.2	1,838.4	-------	1,977.6	2.2
LDT	6,580.8	66,550.3	4,230.4	101.4	461.0	-------	562.4	1.0
HDV	3,167.7	35,526.2	2,171.4	295.2	98.4	-------	393.6	2.0
Sub-Total Gasoline	27,003.9	264,605.5	21,837.9	535.8	2,397.3	-------	2,933.6	5.2
Diesel								
LDV	38.1	157.8	102.1	32.5	18.0	-------	50.5	0.2/1.1
LDT	2.7	5.8	5.1	1.2	0.9	-------	2.1	0.007/0.04
HDV	1,362.8	11,817.4	4,066.5	873.0	218.3	-------	1,091.3	4.0/21.5
Sub-Total Diesel	1,403.6	11,981.0	4,173.7	906.7	237.2	-------	1,143.9	4.2/22.6
Sub-Total Mobile	28,407.5	276,586.5	26,011.6	1,442.5	2,635.0	-------	4,077.5	9.4/27.8
STATIONARY								
Point Sources	4,906.0	250.0	6,681.0	12,520.0	-----	-------	12,520.0	**
Area Sources	31,510.0	17,393.0	9,942.0	1,095.0	-----	627,837.0	628,932.0	**
Sub-Total Stationary	36,416.0	17,643.0	16,623.0	13,615.0	-----	627,337.0	641,452.0	**
Total	64,823.5	294,229.5	42,634.6	15,057.5	2,635.0	627,337.0	645,529.5	**

*Lbs/yr; **Indeterminate

Table D-24. Phoenix Pollutant Dump, Tons/Yr, Base Case 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	19,895.1	159,677.0	19,166.9	123.3	2,325.4	-------	2,448.7	2.3
LDT	5,637.8	49,948.0	5,069.1	34.7	583.8	-------	618.5	0.6
HDV	876.3	8,698.9	616.3	88.4	29.5	-------	117.9	0.6
Sub-Total Gasoline	26,409.2	218,323.9	24,852.3	246.4	2,938.7	-------	3,185.1	3.5
Diesel								
LDV	48.2	199.7	116.3	29.4	23.5	-------	52.9	0.2/1.4
LDT	3.6	7.7	6.5	1.2	1.2	-------	2.4	0.009/0.054
HDV	2,525.2	23,855.8	4,919.6	1,767.1	441.8	-------	2,208.9	8.1/43.5
Sub-Total Diesel	2,577.0	24,063.2	5,042.4	1,797.7	466.5	-------	2,264.2	8.3/45.0
Sub-Total Mobile	28,986.2	242,387.1	29,894.7	2,044.1	3,405.2	-------	5,449.3	11.8/48.5
STATIONARY								
Point Sources	4,901.0	239.0	6,301.0	15,914.0	-----	-------	15,914.0	**
Area Sources	40,202.0	21,733.0	12,521.0	1,351.0	-----	634,421.0	635,772.0	**
Sub-Total Stationary	45,103.0	21,972.0	18,822.0	17,265.0	-----	634,421.0	651,686.0	**
Total	74,089.2	264,359.1	48,716.7	19,309.1	3,405.2	634,421.0	657,135.3	**

*Lbs/yr; **Indeterminate

Table D-25. Phoenix Pollutant Dump, 10-Percent Dieselization Rate, 1985

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	22,365.4	212,648.3	14,958.6	289.8	1,549.0	-------	1,838.8	3.1
LDT	8,715.3	89,119.0	4,870.9	215.0	382.5	-------	597.5	1.7
HDV	4,839.5	69,069.3	3,559.6	355.3	118.4	-------	473.7	2.4
Sub-Total Gasoline	35,920.2	370,836.6	23,389.1	860.1	2,049.9	-------	2,910.0	7.2
Diesel								
LDV	128.8	523.3	418.6	155.4	61.2	-------	216.6	0.6/3.7
LDT	72.6	154.7	148.3	48.1	18.2	-------	67.5	0.2/1.1
HDV	989.8	7,165.9	4,920.2	522.0	130.5	-------	652.5	2.4/12.8
Sub-Total Diesel	1,191.2	7,843.9	5,487.1	725.5	209.9	-------	935.4	3.2/17.6
Sub-Total Mobile	37,111.4	378,680.5	28,876.2	1,585.6	2,259.8	-------	3,845.4	10.4/24.8
STATIONARY								
Point Sources	4,911.0	260.0	7,061.0	11,242.0	-----	-------	11,242.0	**
Area Sources	28,958.0	15,587.0	9,127.0	949.0	-----	636,085.0	637,034.0	**
Sub-Total Stationary	33,869.0	15,847.0	16,188.0	12,191.0	-----	636,085.0	648,276.0	**
Total	70,980.4	394,527.5	45,064.2	13,776.6	2,259.8	636,085.0	652,121.4	**

*Lbs/yr; **Indeterminate

Table D-26. Phoenix Pollutant Dump, Tons/Yr, 10-Percent Dieselization Rate, 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	16,605.6	156,681.3	14,600.7	129.9	1,707.9	-------	1,837.8	2.0
LDT	6,286.5	63,802.1	3,962.5	98.0	424.0	-------	522.0	1.0
HDV	3,167.7	35,526.2	2,171.4	295.2	98.4	-------	393.6	2.0
Sub-Total Gasoline	26,059.8	256,009.6	20,734.6	523.1	2,230.3	-------	2,753.4	5.0
Diesel								
LDV	306.3	1,262.4	807.5	227.9	148.5	-------	376.4	1.5/8.9
LDT	150.3	319.4	272.3	57.9	37.9	-------	95.8	0.4/2.6
HDV	1,362.8	11,817.4	4,066.5	873.0	218.3	-------	1,091.3	4.0/21.5
Sub-Total Diesel	1,819.4	13,399.2	5,146.3	1,158.8	404.7	-------	1,563.5	5.9/33.0
Sub-Total Mobile	27,879.2	269,408.8	25,880.9	1,681.9	2,635.0	-------	4,316.9	10.9/38.0
STATIONARY								
Point Sources	4,906.0	250.0	6,681.0	12,520.0	-----	-------	12,520.0	**
Area Sources	31,510.0	17,393.0	9,942.0	1,095.0	-----	627,837.0	628,932.0	**
Sub-Total Stationary	36,416.0	17,643.0	16,623.0	13,615.0	-----	627,837.0	641,152.0	**
Total	64,295.2	287,051.8	42,503.9	15,296.9	2,635.0	627,837.0	645,768.9	**

*Lbs/yr; **Indeterminate

Table D-27. Phoenix Pollutant Dump, Tons/Yr, 10-Percent Dieselization Rate, 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	17,980.7	147,063.5	17,480.4	105.7	2,116.4	-------	2,222.1	2.1
LDT	5,107.1	45,326.4	4,645.0	29.0	527.2	-------	556.2	0.5
HDV	876.3	8,698.9	616.3	88.4	29.5	-------	117.9	0.6
Sub-Total Gasoline	23,964.1	201,088.8	22,741.7	223.1	2,673.1	-------	2,896.2	3.2
Diesel								
LDV	481.5	1,973.1	1,162.7	290.7	232.5	-------	523.2	2.3/14.0
LDT	231.1	491.4	406.2	73.8	57.8	-------	131.6	0.6/3.5
HDV	2,525.2	23,855.8	4,919.6	1,767.1	441.8	-------	2,208.9	8.1/43.5
Sub-Total Diesel	3,237.8	26,320.3	6,488.5	2,131.6	732.1	-------	2,863.7	11.0/61.0
Sub-Total Mobile	27,201.9	227,409.1	29,230.2	2,354.7	3,405.2	-------	5,759.9	14.2/64.2
STATIONARY								
Point Sources	4,901.0	239.0	6,301.0	15,914.0	-----	-------	15,914.0	**
Area Sources	40,202.0	21,733.0	12,521.0	1,351.0	-----	634,421.0	635,772.0	**
Sub-Total Stationary	45,103.0	21,972.0	18,822.0	17,265.0	-----	634,421.0	651,686.0	**
Total	72,304.9	249,381.1	48,052.2	19,619.7	3,405.2	634,421.0	657,445.9	**

*Lbs/yr; **Indeterminate

Table D-28. Phoenix Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 1985

Sources	HC	CO	NO_x	Particulates: Exhaust or Stack	Particulates: Tires	Particulates: Fugitive Dust	Particulates: Total	BaP*
MOBILE								
Gasoline								
LDV	21,995.0	209,919.1	14,604.3	289.8	1,466.9	-------	1,756.7	3.0
LDT	8,403.6	85,401.9	4,572.4	204.7	349.8	-------	554.5	1.7
HDV	4,839.5	69,069.3	3,559.6	355.3	118.4	-------	473.7	2.4
Sub Total Gasoline	35,238.1	364,390.3	22,736.3	849.8	1,935.1	-------	2,784.9	7.1
Diesel								
LDV	297.9	1,215.7	789.0	362.3	143.3	-------	505.6	1.4/8.6
LDT	203.5	432.7	415.3	136.2	50.9	-------	187.1	0.5/3.1
HDV	989.8	7,165.9	4,920.2	522.0	130.5	-------	652.5	2.4/12.8
Sub-Total Diesel	1,491.2	8,814.3	6,124.5	1,020.5	324.7	-------	1,345.2	4.3/24.5
Sub-Total Mobile	36,729.3	373,204.6	28,860.8	1,870.3	2,259.8	-------	4,130.1	11.4/31.6
STATIONARY								
Point Sources	4,911.0	260.0	7,061.0	11,242.0	-----	-------	11,242.0	**
Area Sources	28,958.0	15,587.0	9,127.0	949.0	-----	636,085.0	637,034.0	**
Sub-Total Stationary	33,869.0	15,847.0	16,188.0	12,191.0	-----	636,085.0	648,276.0	**
Total	70,598.3	389,051.6	45,048.8	14,061.3	2,259.8	636,085.0	652,406.1	**

*Lbs/yr; **Indeterminate

Table D-29. Phoenix Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 1990

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	15,064.8	144,466.1	13,106.3	120.7	1,483.3	-------	1,604.0	1.8
LDT	5,748.2	58,651.0	3,512.4	91.3	366.0	-------	457.3	0.9
HDV	3,167.7	35,526.2	2,171.4	295.2	98.4	-------	393.6	2.0
Sub-Total Gasoline	23,980.7	238,643.3	18,790.1	507.2	1,947.7	-------	2,454.9	4.7
Diesel								
LDV	761.1	3,174.5	2,014.2	570.4	373.1	-------	943.5	3.7/22.4
LDT	344.7	815.4	638.3	150.5	95.9	-------	246.4	0.9/5.2
HDV	1,362.8	11,817.4	4,066.5	873.0	218.3	-------	1,091.3	4.0/21.5
Sub-Total Diesel	2,468.2	15,807.3	6,719.0	1,593.9	687.3	-------	2,281.2	8.6/49.1
Sub-Total Mobile	26,448.9	254,450.6	25,509.1	2,101.1	2,635.0	-------	4,736.1	13.3/53.8
STATIONARY								
Point Sources	4,906.0	250.0	6,681.0	12,520.0	-----	-------	12,520.0	**
Area Sources	31,510.0	17,393.0	9,942.0	1,095.0	-----	627,837.0	628,932.0	**
Sub-Total Stationary	36,416.0	17,643.0	16,623.0	13,615.0	-----	627,837.0	641,452.0	**
Total	62,864.9	272,093.6	42,132.1	15,716.1	2,635.0	627,837.0	646,188.1	**

*Lbs/yr; **Indeterminate

Table D-30. Phoenix Pollutant Dump, Tons/Yr, 25-Percent Dieselization Rate, 2000

Sources	HC	CO	NO_x	Particulates				BaP*
				Exhaust or Stack	Tires	Fugitive Dust	Total	
MOBILE								
Gasoline								
LDV	15,021.1	121,507.7	14,551.3	94.0	1,766.4	-------	1,860.4	1.8
LDT	4,279.3	38,107.4	3,887.4	22.2	440.3	-------	462.5	0.4
HDV	876.3	8,698.9	616.3	88.4	29.5	-------	117.9	0.6
Sub-Total Gasoline	20,176.7	168,314.0	19,055.0	204.6	2,236.2	-------	2,440.8	2.8
Diesel								
LDV	1,197.9	4,956.1	2,924.4	732.3	582.5	-------	1,314.8	5.8/35.0
LDT	578.9	1,230.8	1,019.7	186.9	144.7	-------	331.6	1.4/8.7
HDV	2,525.2	23,855.8	4,919.6	1,767.1	441.8	-------	2,208.9	8.1/43.5
Sub-Total Diesel	4,302.0	30,042.7	8,863.7	2,686.3	1,169.0	-------	3,855.3	15.3/87.2
Sub-Total Mobile	24,478.7	198,356.7	27,918.7	2,890.9	3,405.2	-------	6,296.1	18.1/90.0
STATIONARY								
Point Sources	4,901.0	239.0	6,301.0	15,914.0	-----	-------	15,914.0	**
Area Sources	40,202.0	21,733.0	12,521.0	1,351.0	-----	634,421.0	635,772.0	**
Sub-Total Stationary	45,103.0	21,972.0	18,822.0	17,265.0	-----	634,421.0	651,686.0	**
Total	69,581.7	220,328.7	46,740.7	20,155.9	3,405.2	634,421.0	657,982.1	**

*Lbs/yr; **Indeterminate

APPENDIX E

COMPARISON OF URBAN FREEWAY RESULTS WITH PEDCO ANALYSIS

PEDCo Environmental conducted a study of particulate effects using Kansas City as a model. The results of that work were described in a draft document entitled "Air Quality Assessment of Particulate Emissions from Diesel-Powered Vehicles" (Ref. E-1). Part of the analysis reported in that document entailed the investigation of particulate concentrations near roadways.

Reference E-1 (PEDCo) examined diesel particulate concentrations at a 10-ft high receptor located 13 ft from the edge of a roadway carrying 25,000 vehicles per day. Diesel particulate emission rates of 2.0 g/mi HDV (same as present study) and 0.5 g/mi LDV (vs 0.25 g/mi, present study) were used. Results were reported in terms of annual 24-hour maximum concentrations for a traffic mix based on both best estimate and maximum (25-percent LDV) dieselization rate effects projected to the years 1985 and 1990. The maximum dieselization scenario assumed an HDV diesel mix similar to the present study; therefore, the values for this case, scaled to a traffic rate of 188,000 vehicles per day, should be roughly comparable to the present report's 13-ft receptor results, suitably adjusted to a 0.5 g/mi LDV emission rate.

This comparison is shown in Table E-1. Included in the table are concentration values obtained by applying the Reference E-1 methodology to roadway site positions of 100 and 300 ft. The comparison is made using worst case conditions taken from Table 4-5, adjusted as indicated above. It is seen that at the 13-ft position, the concentrations predicted by the present analysis are about one-third that from Reference E-1, at 100 ft the results of the two methods are comparable, while at 300 ft the present analysis indicates concentrations that are three times those based on Reference E-1.

Table E-1. Comparison of Urban Freeway Results with PEDCo Roadway Analysis (Annual 24-Hour Maximums, μg/m^3 Above Ambient)

Distance from Edge of Roadway, Ft	This Study[1]		PEDCo[2] (Ref. E-1)	
	1985	1990	1985	1990
13	101	155	280	428
100	58	88	46	70
300	45	69	15	23

(1) From Table 4-5 (worst-case estimate), adjusted to 0.5 g/mi LDV.

(2) PEDCo examined effects at one position 13 ft from roadway edge, 10 ft above ground, for a roadway carrying 25,000 veh/day. Values shown here are scaled to traffic count and locations examined in this study, using the methodology described in the PEDCo report (Ref. E-1).

There are many possible reasons for the differences in these results. In addition to effects directly related to input constants (e.g., traffic count, traffic mix, LDT emission factors), the results are also influenced by the respective methodologies and numerous methodology-related assumptions and conditions. Reference E-1 does not provide sufficient information to examine all of these points in detail. One possible significant factor is discussed below.

The roadside dispersion characteristics used as a basis for the 13-ft concentration values reported by PEDCo are shown in Figure E-1. These characteristics were obtained from Reference E-2, a GCA study for EPA entitled "National Assessment of the Urban Particulate Problem." These characteristics primarily represent the dispersion of reentrained roadway dust from vehicular activity on a paved road. Indeed, in describing their work, GCA (Ref. E-2) states:

> The analysis basically addressed the impact of traffic on measured particulate levels with no distinction between reentrained particulates and emissions from tailpipes or tire wear....The majority of the vehicular contributions at monitors close to the road is from reentrained particulates....at least 85 percent of the particulate matter originally suspended due to vehicles results from reentrained particles.

The characteristics of reentrained roadway dust are treated in Reference E-3. That study found that TSP samples collected close to roadways were characterized by relatively large particulates having a mass median diameter of 15μ with about 22 percent by weight greater than 30μ. About 60 percent by weight were found to be of mineral origin. That study determined that the fallout rates of roadway-based particles were: 14 percent at 33 ft from the roadway edge, 26 percent at 66 ft from the roadway edge, and 34 percent at 98 ft from the roadway edge.

These considerations are advanced to suggest that the dispersion characteristics shown in Figure E-1 may be suitable as a measure of reentrained roadway dust, but may not be satisfactory as a representation of

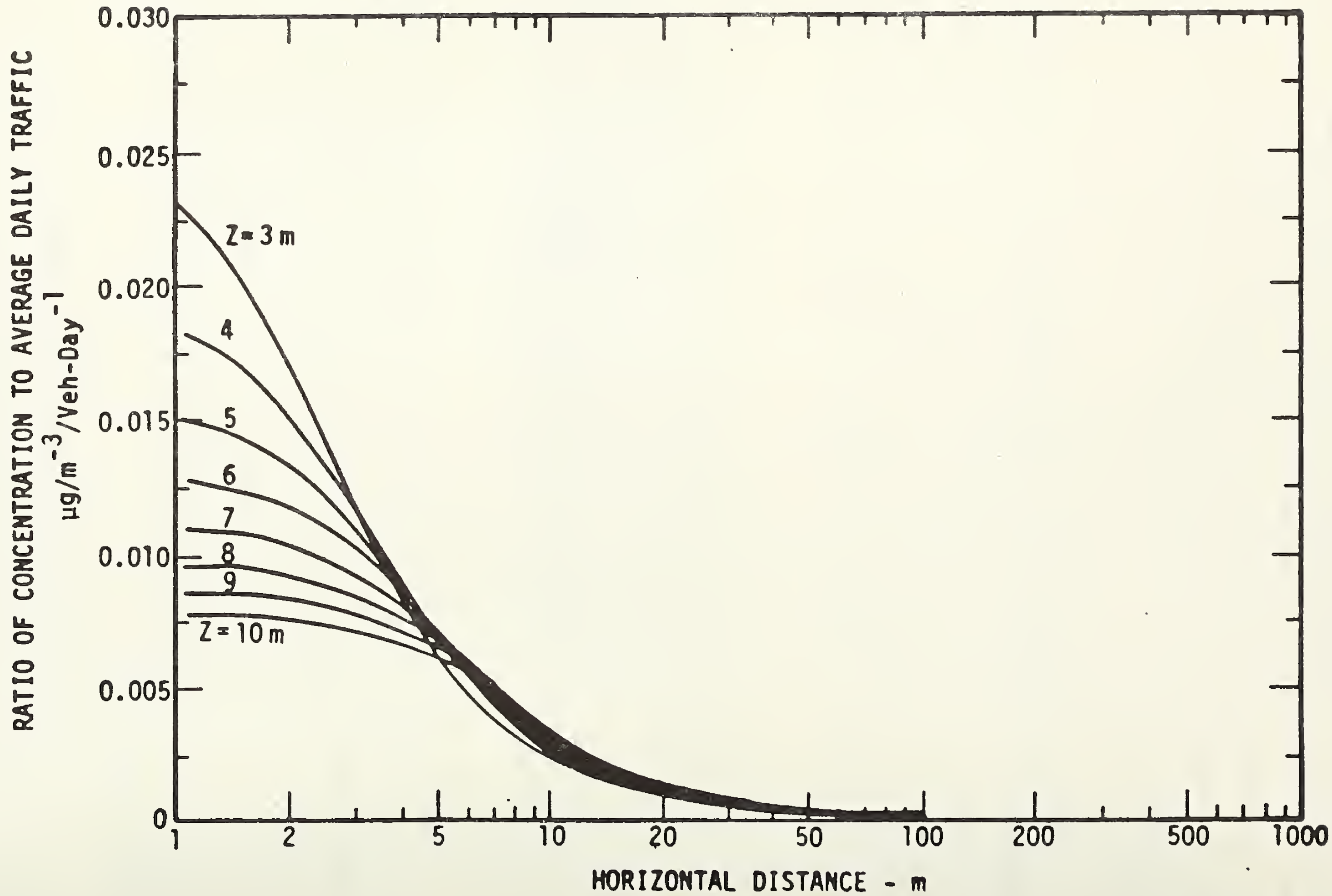

Figure E-1. Dispersion Characteristics for Roadway-Generated TSP Employed in PEDCo Study (Ref. E-1) diesel particulate dispersion characteristics because diesel particulates are significantly smaller and lower in bulk density (~ 0.075 g/cm^3), and therefore may have entirely different aerodynamic characteristics. Recent studies (e.g., Ref. E-4) indicate that 90 percent by weight of the particulates in diesel exhaust are smaller than 1μ and 50 percent by weight are smaller than about 0.3μ.

In contrast to the PEDCo methodology, the present study predicts the dispersion of vehicle exhaust particulates using roadway measurements of vehicle exhaust gas, tracer species, or sulfate particulates which have been shown to behave as a gas. This difference in approach from the PEDCo analysis may account for the effects shown in Table E-1, indicating lower concentrations at distances close to the roadway and higher concentrations at distance remote from the roadway.

REFERENCES

E-1 "Air Quality Assessment of Particulate Emissions from Diesel-Powered Vehicles," Draft, PEDCo Environmental, Inc. Prepared for Pollutant Strategies Branch, Strategies and Air Standard Division, U. S. Environmental Protection Agency, Research Triangle Park, N.C. (December 1977).

E-2 D. A. Lynn, et al, "National Assessment of the Urban Particulate Problem," Report No. EPA-450/3-76-024, GCA/Technology Division, Bedford, Mass. (July 1976).

E-3 K. Axetell and J. Zell, "Control of Reentrained Dust from Paved Streets," Report No. EPA-907/9-77-007, PEDCo-Environmental, Inc., Kansas City, Mo. (July 1977).

E-4 C. J. Vuk, et al, "The Measurement and Analysis of the Physical Character of Diesel Particulate Emissions," SAE Paper No. 760131 (1976).

APPENDIX F

REPORT OF NEW TECHNOLOGY

After a diligent review of the work performed under this contract, it was determined that no new innovation, discovery, improvement or invention was made.

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