THE EFFECT OF METEOROLOGY ON ATMOSPHERIC PARTICULATE CONCENTRATIONS IN HAMILTON, ONTARIO

BY

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ABSTRACT

Ambient air pollution and pollution emitted from point sources, contribute to the total suspended particulate loadings measured at various monitoring stations, in any given area. Studies have shown that various meteorological variables may influence the concentration of particulates measured at these stations. 1989 data, from monitoring stations throughout Hamilton, Ontario, in conjunction with meteorological data from the Mount Hope airport, have been used to reveal, and to explain the aforementioned relationships. Results from graphical analysis, supports past findings from Stewart and Matheson (1967), Rouse and McCutcheon (1970), Dobroff (1990) and others, by showing that winds derived from a northern sector increase mean particulate loadings, and that wind speeds tend to be inversely related to measured particulate concentrations. In contrast to supporting findings from the graphical analysis, statistical ordinary least squares regression showed that for more stations than not, most parameter coefficients were not statistically significant. Results from the coefficient of determination show that none of regressions employed (linear, linear-log and log-log) could explain the relationship between the independent meteorological variables and the dependent variable (particulate concentration at a given monitoring site) with great precision. It follows that a non-linear correlation may well explain the dependence of particulate loading on wind speed, wind direction, mean temperature and total precipitation, and that source, (point and fugitive emissions), and other factors play important roles in this complex relationship.

ACKNOWLEDGEMENTS

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CHAPTER 1 INTRODUCTION

1.1 OBJECTIVE

The main objective of this research is to examine the trends in the meteorological variables and Total Suspended Particulate (TSP) loadings during the year 1989, and to see if any relationship exists between the various meteorological variables, source factors and TSP loadings, to support past findings.

Air quality is a major concern of residents in the Hamilton region given the large industrial core and their associated emissions. With technology and innovation there have been major improvements to the type, quality, and amount of emissions injected into our atmosphere. Given the need for economic development to maintain the present standard of living, air pollution will continue to pose a threat to humans and to their environment.

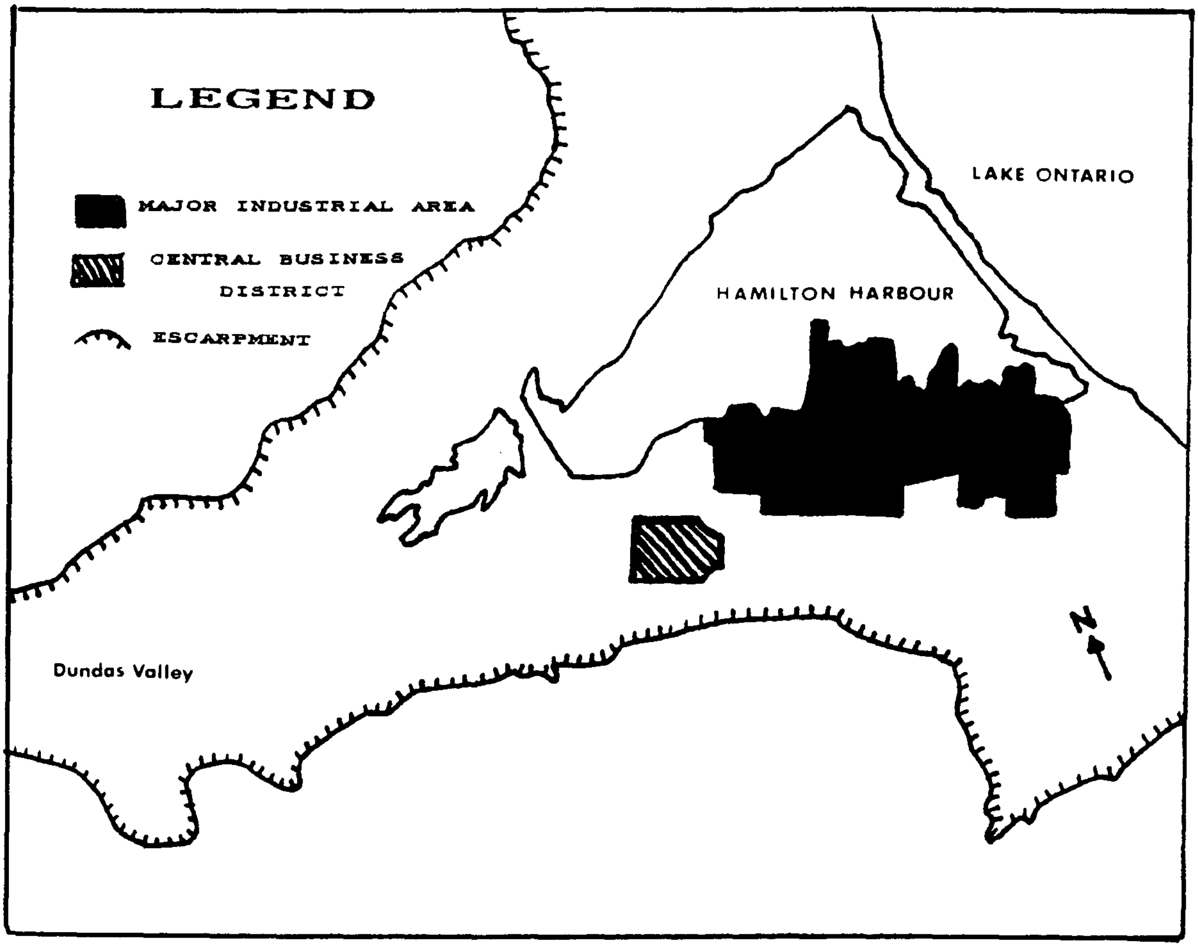
1.2 SITE DESCRIPTION: TOPOGRAPHY AND MORPHOLOGY

Hamilton is located on the western shore of Lake Ontario 70 km south-west of Metropolitan Toronto. The city covers about 110 km^2 and has an approximate population of 300 000 (Farhang, 1983). There are three controls which interact with the regional climatology of the region to influence the patterns of air pollution. These are topographic setting, urban morphology and proximity to Lake Ontario (Rouse and McCutcheon, 1970). The Niagara Escarpment sharply divides the city into upper and lower sectors with an average height difference of 100 m. The terrain is essentially flat minus the deep re-entrant valleys which cut the escarpment, the prominent ones being the Dundas Valley to the west and the Redhill Creek Valley to the east. The city if made up of the heavy industrial sector (industrial fugitive and direct emissions), along the southern shore of Hamilton Harbour; the commercial sector in the central part of the city, and the residential area which is mixed with light industry and some commercial properties (fig. 1).

1.3 METEOROLOGY AND CLIMATOLOGY

Hamilton, located at 43° N, 79° W, has a continental climate modified somewhat by the presence of Lake Ontario. The lake modifies both summer and winter temperature extremes and provides an added moisture source to augment precipitation. On average, precipitation is at a minimum in February and at a maximum in August. Winter precipitation is mainly a result of frontal activity (causing temporary temperature inversions) while the summer regime is controlled mainly by convection. The coldest months are December to February and the warmest are July and August.

FIGURE 1



LOCATION AND URBAN MORPHOLOGY OF HAMILTON after Rouse and McCutcheon (1970)

The annual mean temperature above the escarpment is approximately 1°C below that of the lower city and the wind speeds are slightly higher for the latter sector. The dominant wind directions in Hamilton are south-westerly and westerly (based on four local stations over sampling periods from six to ten years) while the next most predominant wind directions are north-easterly and easterly. The first set of wind directions is more common in winter whilst the latter set predominates in spring. Land and Lake breeze phenomena occur over an eight month period due to the additional heat input from industrial sources. These phenomena rarely extend beyond the escarpment but their synoptic effect creates local conditions of strong fumigation (Farhang, 1983).

1.4 BACKGROUND KNOWLEDGE

There are two groups of factors which influence and determine the amount of pollution at a given location: (i) the nature of emission, and (ii) the state of the atmosphere. Pertinent is the fact that despite constant emissions, air quality can, and will fluctuate. If a complete analysis is to proceed, the rate of emission, source, and shape of the emission area, duration of release and the effective height of pollution injection into the atmosphere must be known (Oke, 1987).

1.4.1 NATURE OF EMISSION

Sources of suspended particulates in Hamilton can be apportioned into four categories: (a) Background/ambient sources, which are due to the long range transport and diffusion of particles from other areas into the Hamilton region; (b) Fugitive, "area" sources; (c) Industrial point sources; (d) Unexplained (O.R.F. et al, 1982; Farhang, 1983).

Fugitive sources include unpaved and paved roads, agricultural tilling, agricultural wind erosion, construction sites and mine tailings. The total dust emissions from travel on roads depends heavily on the overall travel time, highway class (e.g. interstate, arterial, collector, local), the locale (i.e. urban, rural), road surface type (i.e. elemental composition), surface moisture content, and vehicle speed (Evans and Cooper, 1980). Point sources include areas where the pollutant is injected directly into the atmosphere via a known, quantifiable source (i.e. smokestacks). These sources are mainly concentrated around the industrial core on the Beach strip of Hamilton Harbour.

Quantified emissions from point sources have been extensively reviewed in the literature. Studies from Barton and Dobson (1985), and others, have shown that emission estimates from re-entrained dust, direct exhaust emissions and tire wear from major transportation corridors to be of minimum consequence to overall TSP measures. Other sources of TSP include infrequent street cleaning, home heating (O.R.F. et al, 1982) and entrained road salt.

1.4.2 STATE OF THE ATMOSPHERE

Atmospheric controls such as vertical stability in the boundary layer, wind and precipitation influence pollutant concentrations as a result of their effect on dispersion, diffusion and transport. The aggregation of pollutants is predominant under sunny, daytime conditions, especially in summer (see Oke, 1987). Temperature inversions which are often experienced in the Southern Ontario region result in elevated levels of suspended particulates (Dobroff, 1990). Greater wind speeds have a higher pollutant dilution potential than calmer winds. Wind direction has its importance in terms of the transportation of the effluent. It also determines the path followed by pollutants after emission. The coincident alignment of source inputs due to a particular wind direction may result in 'multiple pollution inputs'. From the above, it can be seen that the greatest potential from pollution exists with weak winds as turbulent diffusion and horizontal transport are restricted.

Local circulation systems, three of which are common to the Hamilton region, (land/lake breezes, city winds, and low level stable inversions), are not good contrivances for cleansing pollutant laden air (Rouse and McCutcheon, 1970; Oke, 1987).

Pollutant removal is achieved by various means. In terms of meteorological influences, 'washout', a below cloud base occurrence, is of primary importance to particulate loadings of small particles. More important than absolute precipitation amounts the rainfall rate (see Oke, 1987).

CHAPTER 2 A REVIEW OF EXISTING LITERATURE

2.1 INTRODUCTION

Particulate matter is of interest to scientists, social scientists and to the public at large, as a result of the threats it poses on human health and the environment.

Beyond threshold values, suspended particulates can increase sensitivity of asthmatics and bronchitics and may even contribute to respiratory disease. Particulate matter also affects vegetation, reduces visibility, corrodes and soils certain materials (Bradley, 1990).

The Ontario Ministry of the Environment (MOE) monitors air quality at various stations on a regular basis to ensure that industrial emissions are regulated. The Ministry assesses emissions of total suspended particulates at 19 sites in Hamilton (Dobroff, 1990), on hourly, daily, monthly and yearly bases.

Extensive reports are written on a yearly basis, by the MOE, to evaluate trends in emissions in relation to particulate loadings at various measuring stations. These reports are mainly concerned with monitoring emissions, not on how and when meteorological parameters influence atmospheric particulate levels. There have been many studies on the role of meteorology and climatology on atmospheric particulates levels (Stewart and Matheson, 1967; Rouse and McCutcheon, 1970; Brooks and Salop, 1983; Farhang, 1983; Bouchertall, 1989; Simpson and Miles, 1990 and others), yet this study will be partial to 1989 figures.

2.2 MEASUREMENT TECHNIQUES

The relative amounts of particulates emitted to the atmosphere depends upon the location of the source, the season, the type of activity found in the area, etc. (A.C.S.C.E.Q., 1982). Various methods are used to measure atmospheric particulates. The MOE uses three types of instruments for the measurement of particles each relating to a specific particle size range:

(a) Dustfall jars measuring heavy material, generally greater than 10 microns in diameter.

(b) High volume samplers measuring suspended particulates ranging in size from submicron to 50 microns.

(c) Co-efficient of haze [COH] tape samplers measuring mostly fine material - from submicron to about 10 microns (Dobroff, 1990: 16).

Findings from COH tape samplers are further used in conjunction with sulphur dioxide concentrations to calculate the air pollution index (API). The API is a warning system used to alert the public to pollution levels in a given region at a particular time. The API index differs depending on the region being monitored.

Dustfall is sightly material which settles out of the atmosphere in response to gravity. It is collected in plastic jars over a 30 day period. The resultant material is weighed and is expressed in terms of a deposition rate of gms/m^2/30 days (Dobroff, 1990). Suspended particulate amounts are expressed in terms of COH units (suspended material that is most likely to reach the lungs) and are determined by drawing a known volume of air through a portion of the tape and then measuring the reduction of the light transmittance relative to a clean tape (Bradley, 1990).

TSP concentrations are measured by yet another method. The monitoring method presently used is by High Volume Sampler. Air is drawn through a filter at an approximate rate of 1.4 m^3/min. for particulate capture. This is followed by a daily mass weighing of the particulates found in the filter. The cutoff diameter for the filter depends on wind speed as it is that for which, "50% of the particles are collected and 50% rejected by the sampler inlet." (O.R.F., 1982: 4). TSP is computed in terms of ug/m^3 (Bradley, 1990).

Other methods employed to measure fugitive emissions include "Quasistack" sampling, roof monitoring, exposure profiling, and upwind-downwind sampling. These sampling methods are generally employed for fugitive gaseous emissions (Budiansky, 1980). Particle samples measured on wet days can be compared to those measured on dry days to establish the bulk fugitive contribution to total emission amounts. Non-point emissions from roads and wind erosion are suppressed during wet periods and therefore seasonally, monthly or daily particulate levels can be used to reveal the influence of non-point emissions (Budiansky, 1980) and could possibly account for particulate differences between sites.

2.3 MODELS, STRATEGIES, AND PAST FINDINGS

Strategies and models have been devised in order to curb and control emissions (e.g. Simpson and Miles, 1990). Models such as this assume that "a simple inverse relationship exists between the percentiles of the wind speed and air pollution data sets." (Simpson and Miles, 1990: 84). Bouchertall (1989), in his studies on the coast of the Baltic Sea found that atmospheric particulate matter showed a seasonal variability. Prevalent wind patterns in that area resulted in maximum loadings in winter and minimum loadings in summer. Daily values of atmospheric particulates showed variations which were significantly correlated with wind direction (Stewart and Matheson, 1967; Bouchertall, 1989). Based on studies in Southeastern Virginia using regression analysis, Brooks and Salop (1983) found that mass loading (TSP concentrations) can be predicted via two meteorological parameters: pressure and wind direction.

Relating High Volume sampler results to wind direction cannot be done properly without overcoming certain difficulties. Correlation attempts of this sort have been unsuccessful in the past, because a given sampler may accumulate high loadings due to a few hours of wind crossing over a major pollution emission source, while the prevailing wind for the majority of the day may be from an opposing direction. As a result, it is suggested that large samples, and only data having wind directions coming from a "Northern", (NNW-E) or "Southern", (SSE-W) sector during the entire twenty-four hour period, be used, to avoid the ambiguity of results derived from shifting wind directions (Stewart and Matheson, 1967; Farhang, 1983). Past studies from Weisman et al (1969) revealed the linkage of high pollution levels with low wind speeds, north and north-easterly winds and winter months. Rouse and McCutcheon (1970), in their study on air pollution in Hamilton, found that low-volume aerosol counts were twice as high under the influence of easterly winds. They also revealed two pollution cells in the Hamilton region: one in the heavy industrial zone and another in the central business district.

CHAPTER 3 METHODOLOGY

3.1 DATA SOURCES

The meteorological data were collected daily (wind data on an hourly basis) at the Hamilton airport in Mount Hope and were obtained from the monthly meteorological summary compiled by Environment Canada, Atmospheric Environment Service. Air quality data along with wind data for the lower city were collected by the Ontario Ministry of the Environment and were received from Frank Dobroff from the MOE's West Central Branch in Hamilton, Ontario. Air quality data ran on a once every sixth day cycle (Dobroff, 1990). The time-series is comprised of 1989 values as they were the most recent, complete set of records available (appendix).

3.2 DATA SELECTION AND ORGANIZATION

All of the data received was divided into seasons to simplify graphing procedures. As only 1989 values were considered, the beginning of the winter season which commenced on December 21, 1988 was omitted, as were the values after December 20, 1989. Studies from Rouse and McCutcheon (1970), used only pollution measurements where the wind direction was constant for at least eight hours, and Stewart and Matheson (1967) considered only samples taken on days when the wind direction during the entire 24-

hr sampling period was from either of the two 180° sectors (north portion (from NW clock-wise to E) and south portion (from SE clock-wise to W)). In the forthcoming analysis, only periods where at least 91% of the 24-hr period had winds coming from either of the two sectors (the northern sector from E to W, and the southern sector of similar orientation). The data were expanded to include 91% of daily wind values with the same origin rather than 100%, as in the study done by Stewart and Matheson (1967). This was done to increase the significance of the findings, as using procedures employed by Stewart and Matheson (1967) would leave little or no data to analyze statistically. The division scheme is based on the topography and morphology of Hamilton. North winds would disperse pollutants from the industrial core of the city into the downtown commercial and residential area, thereby increasing loadings found in these regions. Winds originating from the south would tend to disperse particulates onto Hamilton Harbour and Lake Ontario, away from the population centre (Rouse and McCutcheon, 1967; Farhang, 1983; Oke, 1987; Dobroff, 1990). Before pursuing the analysis it was assumed that there was a constant cycle of point and ambient emissions in 1989 (i.e. that pollutants were emitted at a constant rate), and that there were no plant shutdowns during the measurement period or changes in pollution abatement systems. This was found to be the case for emissions at Stelco, Hilton Works

(Stewart, personal communication, 1991).

The rationale behind the station groupings used for analysis were based on location, proximity to each other and similar surroundings. The monitoring station were grouped in twos or threes, based on the preceding criteria (table 1, fig. 2).

3.3 DATA MANIPULATION

The following report is analyzed in two parts. The first section relies on qualitative graphical analysis. The data is divided into seasonal components, as previously discussed, and plots of particulate loadings against time, in Julian days, were drawn for each measuring station and for selected meteorological parameters. Daily mean temperatures were not analyzed in this section of the analysis. The plots were analyzed in search of a variety of trends, to see if any striking patterns were evident, with regards to the location of high and low loadings, and to see whether or not they coincided with meteorological extremes.

The second section of the analysis deals with inferential statistics in the form of regression analyses. Four types of regressions were performed:

(1) ordinary least squares (OLS) linear regression

(2) OLS linear-log regression

(3) OLS log-log regression

TABLE 1

DESCRIPTION OF SECTION LOCATIONS

GROUP #	STATION #	STATION NAME	WIND SPEED MEASUREMENT LOCATION	RATIONALE FOR GROUPINGS
A	29012	Burlington/Wellington	lower city	NE part of the city
A	29122	Dundurn/York	lower city	SE section of Hamilton Harbour
A	29067	Hughson N./Macaulay	lower city	E of major industrial area
B	29011	Burlington/Leeds	lower city	S of Burlington St.
B	29025	Barton/Sanford	lower city	S of major industry
B	29113	Gertrude/Depew	lower city	located between James St. and Gage Ave.
C	29119	Morley/Parkdale	lower city	along finges of the eastern portion
C	29102	Beach Blvd./Towers	lower city	of the major industrial sector
D	29017	Chatham/Frid	lower city	S of Main St. W.
D	29098	Bay/Main West	lower city	W of James St.
D	29118	Main West/Hwy 403	lower city	near a busy traffic intersection
E	29000	Elgin/Kelly	lower city	middle section of Hamilton
E	29009	Kenilworth/Whitney	lower city	highly congested area
E	29089	Barton/Nash	lower city	
F	29087	Cumberland/Prospect	lower city	S of King and Main Sts.
F	29130	Ewen/Whitney	lower city	dispersed around the foot of the
F	29135	Mt. Albion/Albright	lower city	Niagara Escarpment
G	29114	Vickers/East 18th	upper city	escarpment location (upper city)
G	29124	Laurier/Columbia	upper city	

N.B. Two groups of wind speeds were used in the study. The first wind speed measurement location is station 29026 (fig. 2) at the Woodward Ave. treatment plant (Dobroff, 1990), and is used to represent wind speeds for the lower city. The second set of measurements from the weather station at Hamilton Airport in Mount Hope, represent wind speeds on the mountain.

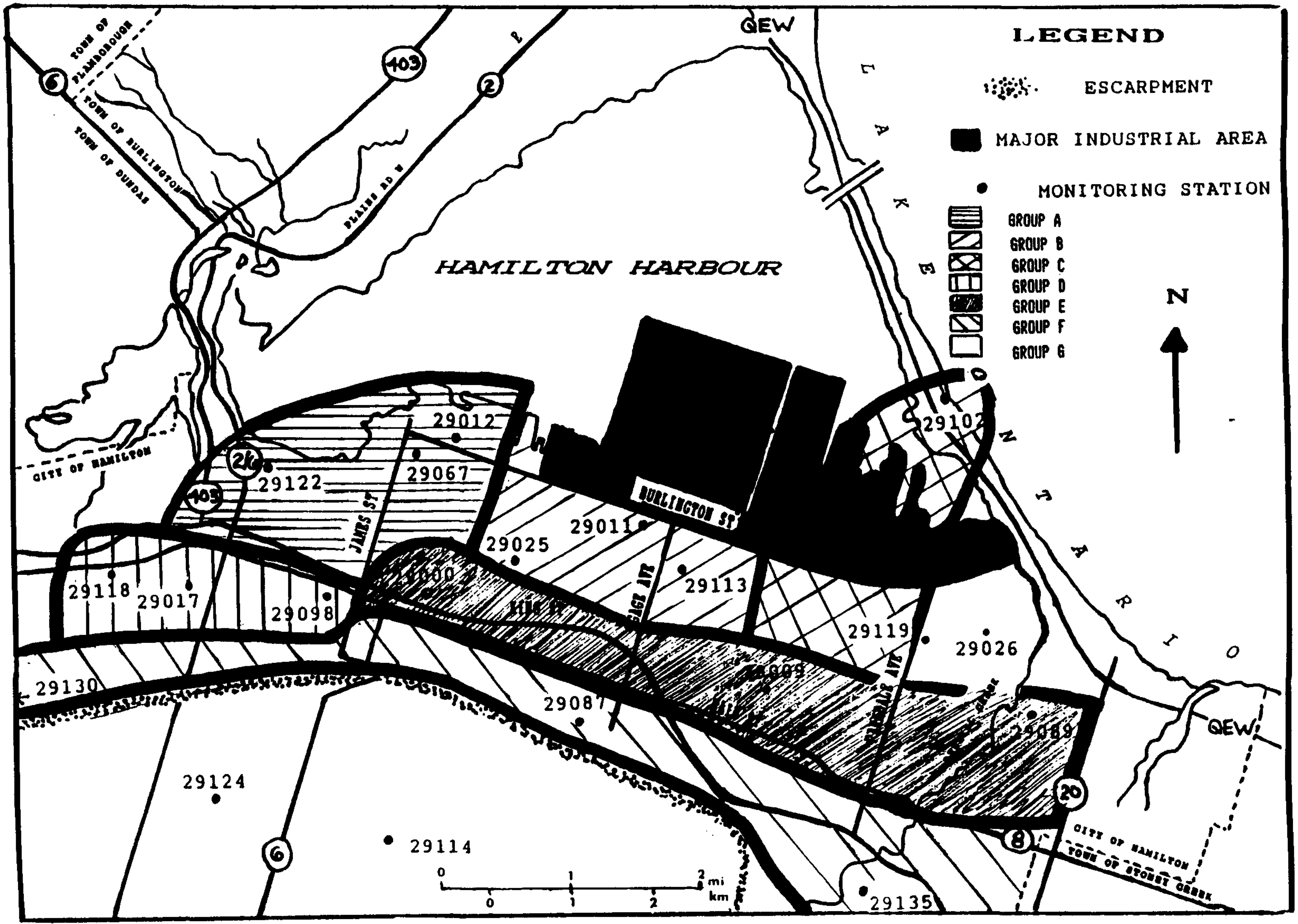


FIGURE 2

HAMILTON AIR MONITORING NETWORK

SECTION LOCATIONS

After Dobroff (1990)

(4) OLS linear-log regression with a lag factor[1] The 'Shazam' statistical package was used to perform the analysis. The purpose of this type of analysis was to measure the coefficient of determination (R-squared), to see the proportion of the variation in the dependent variable (particulate loadings at a given site location), as "explained by" the independent variables (wind speed, wind direction, mean temperature and the total precipitation). This analysis was also used to measure estimated coefficients for the regression equation, for each measuring site, and to measure T-ratios with which statistical tests of significance could be performed.

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1. the lag factor is a function used to see whether loadings from time t-1 have an effect on loadings at time t.

CHAPTER 4 RESULTS

4.1 OBSERVATIONS

Wind speed, precipitation and high-volume sampler plots are seen on figures 3-34, mean measurements are seen on tables 2-4, and isopleth maps are seen on figures 35-38.

4.1.1 JANUARY 4 - MARCH 20 (DAY 4 - DAY 76)

During this winter period three peaks in wind speed were present on days 22-28, day 40 and on day 76. High wind speeds on day 40 corresponded to high particulate loadings at all stations. Similarly, day 10 was a peak loading period for TSPs at all stations. Precipitation at this time was trace. There was a lull in wind speed on day 34 but this did not correspond to drops in particulate loadings at most of the stations. Day 64 experienced higher wind speeds than its two surrounding measurement periods. The comparison between wind speeds and particulate loadings did not show any observable relationship. Calmer conditions were recorded on day 70. Calmer conditions appear to be inversely related to the particulate loadings (exceptions: station 29012, 29113, 29119, 29102 and 29089). Day 76 was marked with approximately 18 mm of rain, high wind speeds, and low loadings. During this season, peak season loadings were centred around day 40, at all stations. The maximum loading was found on day 40, at station 29017, with a value of 194 ug/m^3 while the minimum loading was found on day 34, at station 29122 with a reading of 11 ug/m^3. The winter means varied amongst the stations from between 42.23 ug/m^3 (29087) and 99.23 ug/m^3 (29011). The prevailing wind direction was from the south.

4.1.2 MARCH 21 - JUNE 20 (DAY 82 - DAY 166)

The spring season showed lower overall wind speeds than the winter season, ranging from 3.5 - 16 km/hr for the lower city and from 11 - 27 km/hr on the escarpment, with mean values of 9.33 km/hr and 16.30 km/hr respectively. Wind speed peaks were found on days 88, 100, 118, and a general rise was found between days 142 - 154 at the lower city station. The upper city wind patterns were similar, with an added peak at day 130. High particulate loadings were predominantly centred around day 136 and day 142. High loadings were also recorded on day 160 for most stations excluding stations 29113, 29102, 29114 and 29124. This was coincidental with a wind shift from WSW to ENE which would act to push pollutants from the industrial sector towards the city. Minimum values were recorded on day 130 for most stations. Station 29017, which is located around highway 2 and Main St. exhibited sporadic fluctuations in particulate loadings. Loadings during the spring season had a minimum value (7ug/m^3) on day 100, at station 29114 on the mountain, and a maximum (243 ug/m^3) on day 136 at station 29017, at highway 2 and Main St. The spring means varied between 37.15 ug/m^3 (29130) and 144.80 ug/m^3 (29011). The prevailing wind direction was from the north. There is no apparent seasonal trend in particulate loadings for this period, loadings appear to be haphazard and sporadic.

4.1.3 JUNE 21 - SEPTEMBER 20 (DAY 172 - DAY 262)

In summer season, wind speed (especially at the lower city) was relatively constant, with minor, regular fluctuations. The wind speed for the upper city peaked on days 178, 202, and 244. Speeds ranged from 4 km/hr (days 172 and 250) to 13 km/hr, for the lower city, and from approximately 6 km/hr (day 250) to 21.20 (day 202) in the upper city. Precipitation was minimal throughout the season with a small increase during day 208 when wind speeds were relatively low. A large precipitation input was found on day 244 (30.4 mm). For all stations except for 29119, peak loadings occurred on day 184 when the wind speed was below the mean for both the upper and lower city sections. Similarly, all stations peaked on day 214 when the wind speeds were at a peak and precipitation was at a minimum. Particulate deposition was at a minimum for almost all stations on day 220. The minimum reading for particulates in the summer of 1989 was 22 ug/m^3 (29135) on day 220 and the maximum reading was 220 ug/m^3 (29102) on day 214. The means varied from a low of 37.25 ug/m^3 (29130) to a high of

134.5 ug/m^3 (29011). Southerly winds prevailed.

4.1.4 SEPTEMBER 21 - DECEMBER 20 (DAY 268 - DAY 352)

Fall figures showed a definite high and low in terms of wind speed on days 292 and 298 respectively. Maximum values reached the 30 km/hr and 40 km/hr mark for the lower and upper city stations respectively. Another small wind speed hike was centred about day 280. Precipitation frequency is greater than 'rivalling' seasons. Aside from the few small anomalies (aforementioned), wind speed was relatively constant, with minor fluctuations about the 12 km/hr (lower city) and 18 km/hr (upper city) marks. Relatively high loadings were found on day 298, at all stations, corresponding to low wind speeds. Similarly, day 292, boasting very high wind speeds at both the upper and lower city stations, was found in consequence with low loadings at all TSP measuring stations. Day 274 and day 328 showed spike in loadings and depressed wind speeds. The opposite situation is encountered on day 280 when high wind speeds corresponded to low wind speeds at most stations. Minimum loading occurred on day 280 at station 29114 with a value of 7 ug/m^3. The maximum loading was found on day 298 at station 29011 and had a reading of 216 ug/m^3. The prevailing wind direction for the fall season was from south.

4.1.5 SUMMARY

Consistent daily variations were seen throughout the measurement period.

TABLE 2

1989 HI-VOL DATA SUMMARY HAMILTON condensed

		WIND SPD [below esc] (km/hr)	WIND SPD [above esc] (km/hr)	mean temp. (°C)	PREDOM. DIRECTn	TOTAL PRECIPn (mm)
WINTER	MEAN	13.92	20.49	-4.03	from S	2.18
	MIN	6.00	11.20	-17.20		0.00
	MAX	22.00	34.20	2.00		18.20
SPRING	MEAN	9.33	16.30	9.07	from N	1.71
	MIN	3.00	11.20	-3.80		0.00
	MAX	17.00	26.50	18.30		6.80
SUMMER	MEAN	8.25	12.23	19.04	from S	2.28
	MIN	4.00	6.00	12.80		0.00
	MAX	13.00	21.20	23.20		30.40
FALL	MEAN	12.07	18.91	3.30	from S	1.87
	MIN	3.00	7.80	-12.50		0.00
	MAX	31.00	40.40	14.50		9.50

TABLE 3

1989 HI-VOL DATA SUMMARY HAMILTON CONDENSED

TOTAL SUSPENDED PARTICULATE (ug/m^3)

		29000	29009	29011	29012	29017	29025	29067	29087	29089	29098
WINTER	MEAN	73.15	60.08	99.23	63.67	83.92	80.85	62.46	59.92	61.17	43.92
	MIN	48.00	36.00	49.00	31.00	37.00	29.00	27.00	29.00	34.00	17.00
	MAX	144.00	98.00	154.00	159.00	194.00	153.00	168.00	152.00	100.00	92.00
SPRING	MEAN	103.14	82.33	144.80	80.33	143.58	114.47	62.64	72.60	88.13	75.53
	MIN	48.00	39.00	64.00	46.00	45.00	52.00	35.00	40.00	42.00	24.00
	MAX	171.00	154.00	251.00	158.00	243.00	200.00	134.00	134.00	168.00	129.00
SUMMER	MEAN	97.00	86.73	134.50	77.50	119.00	91.93	66.06	61.50	88.29	75.40
	MIN	52.00	45.00	70.00	46.00	50.00	27.00	41.00	31.00	45.00	42.00
	MAX	149.00	143.00	215.00	125.00	213.00	149.00	115.00	110.00	158.00	128.00
FALL	MEAN	67.92	49.67	94.07	60.73	99.14	67.64	49.53	43.00	59.87	46.53
	MIN	20.00	23.00	45.00	20.00	27.00	21.00	16.00	15.00	18.00	14.00
	MAX	131.00	111.00	216.00	114.00	185.00	139.00	99.00	83.00	147.00	89.00
	YR. MEAN	85.30	69.70	118.15	70.56	111.41	88.72	60.18	59.26	74.36	60.35

TABLE 4

1989 HI-VOL DATA SUMMARY CONDENSED

TOTAL SUSPENDED PARTICULATE (ug/m^3)

		29102	29113	29114	29118	29119	29122	29124	29130	29135
WINTER	MEAN	95.08	91.08	62.18	56.31	89.00	47.85	53.46	42.23	46.77
	MIN	52.00	44.00	44.00	25.00	44.00	11.00	27.00	27.00	31.00
	MAX	184.00	152.00	120.00	144.00	154.00	162.00	129.00	90.00	91.00
SPRING	MEAN	76.40	139.43	76.80	61.60	92.20	46.53	63.93	37.15	52.07
	MIN	35.00	52.00	7.00	23.00	43.00	28.00	33.00	18.00	23.00
	MAX	127.00	219.00	141.00	120.00	149.00	125.00	114.00	82.00	120.00
SUMMER	MEAN	98.87	126.75	68.13	58.94	106.07	67.25	80.54	37.25	47.81
	MIN	30.00	67.00	37.00	31.00	58.00	44.00	32.00	23.00	22.00
	MAX	220.00	191.00	97.00	99.00	200.00	187.00	154.00	59.00	90.00
FALL	MEAN	90.73	90.47	41.50	45.83	83.47	47.13	51.54	26.87	36.20
	MIN	15.00	36.00	7.00	21.00	38.00	18.00	14.00	9.00	10.00
	MAX	152.00	182.00	95.00	67.00	131.00	84.00	132.00	44.00	66.00
	YR.MEAN	90.27	111.93	62.15	55.67	92.68	52.19	62.37	35.88	45.71

1989
METEOROLOGIC AND PARTICULATE TRENDS
HAMILTON, ONTARIO

PRECIPITATION AND WIND SPEED PLOTS
(figures 3-6)

HIGH-VOLUME SAMPLER LOADING PLOTS
FOR MONITORING STATIONS IN HAMILTON
(figures 7-34)

Days 4-76............. WINTER
Days 82-166........... SPRING
Days 172-262.......... SUMMER
Days 268-352.......... FALL

FIGURE 3

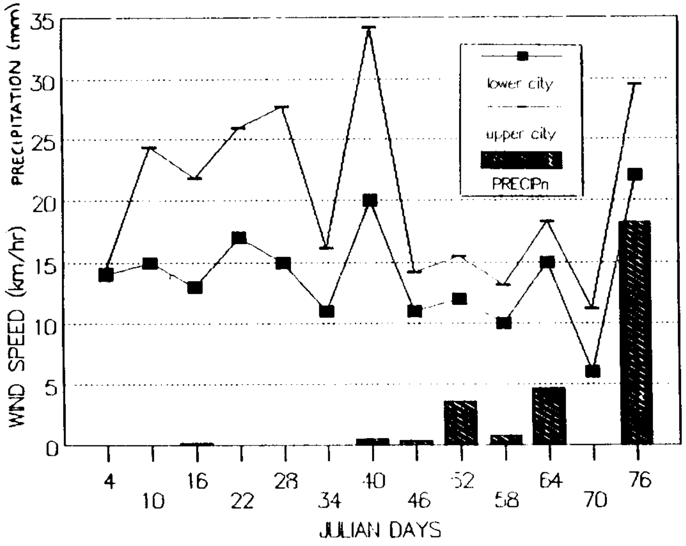


FIGURE 4

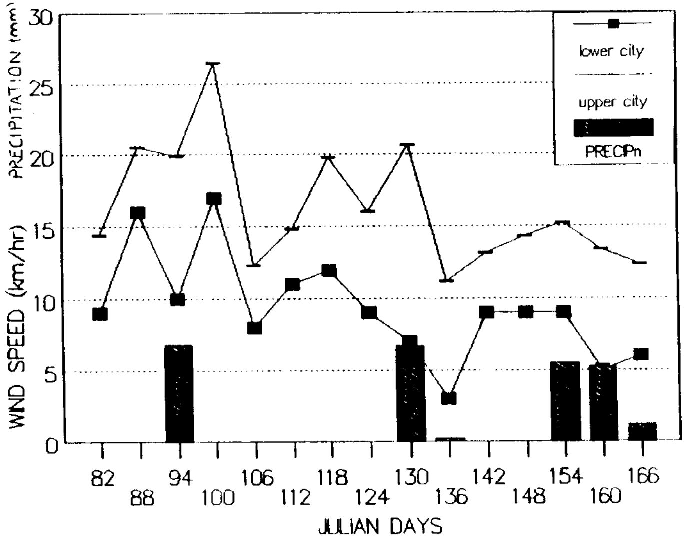


FIGURE 5

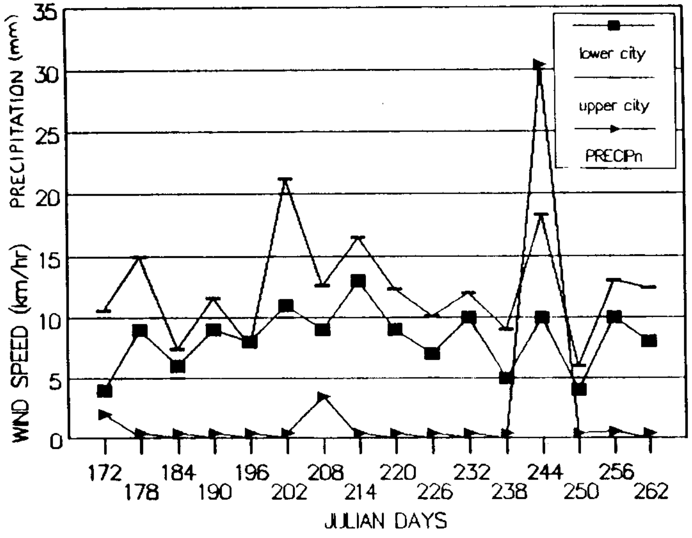
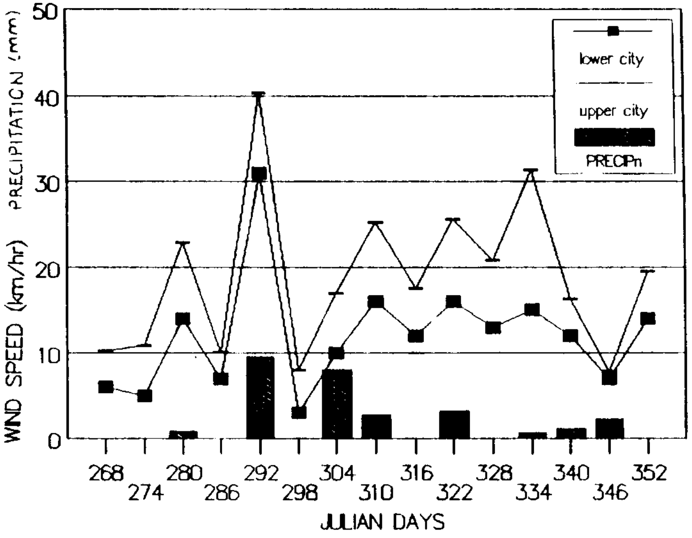


FIGURE 6



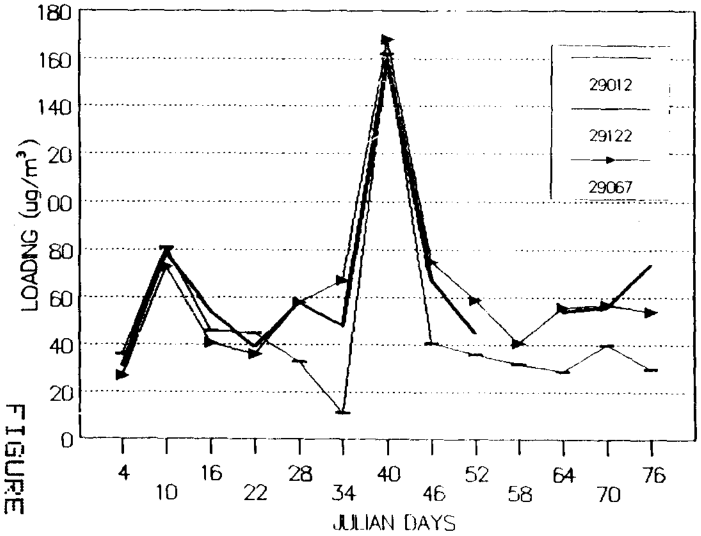


FIGURE 7

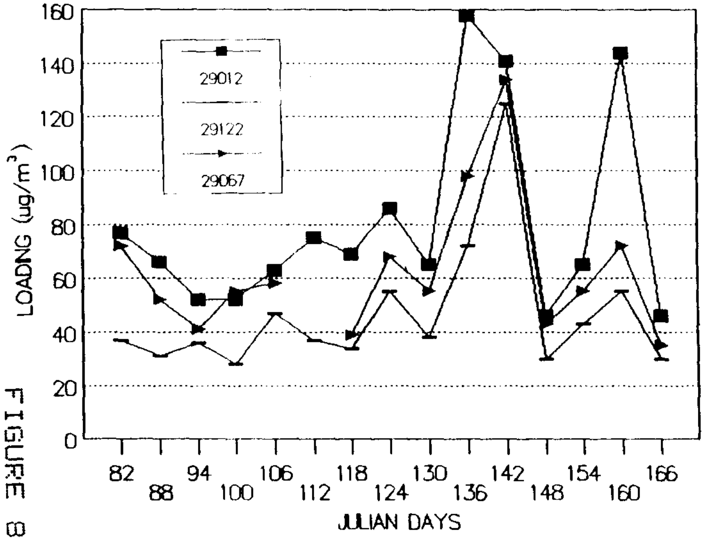


FIGURE 8

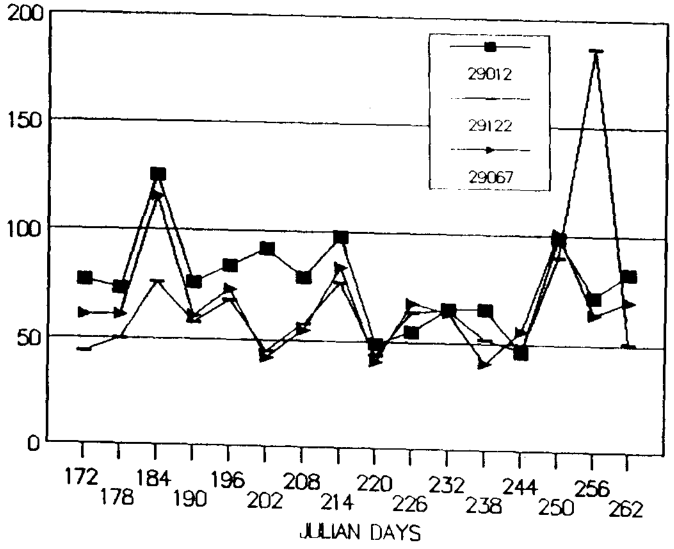


FIGURE 9

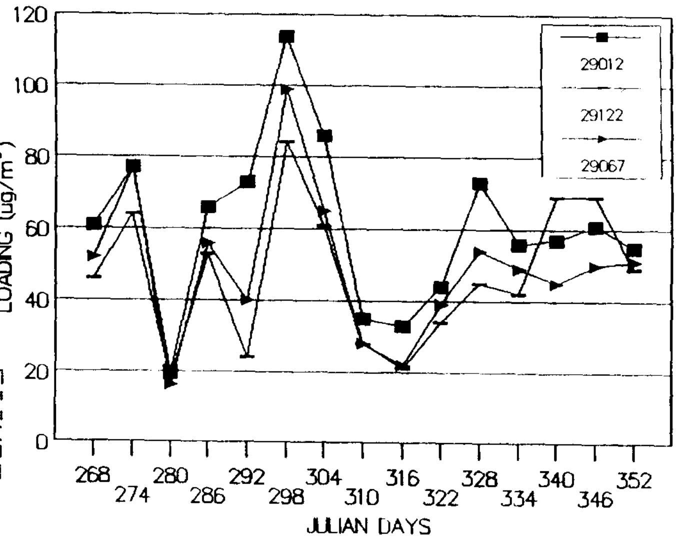


FIGURE 10

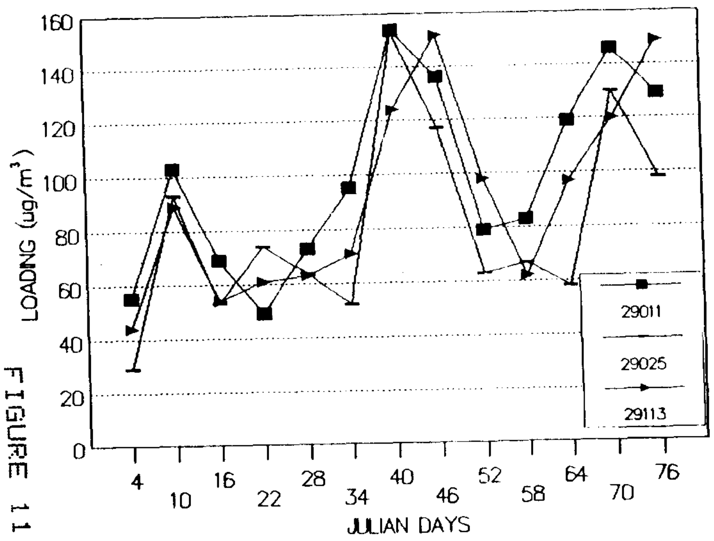


FIGURE 11

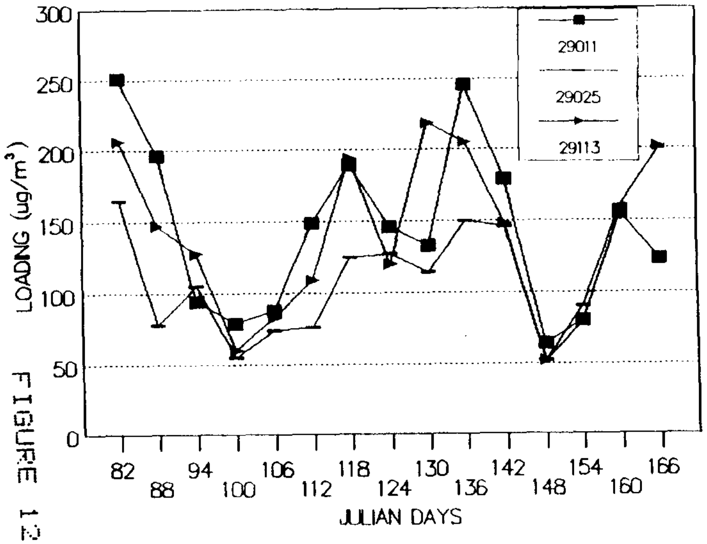


FIGURE 12

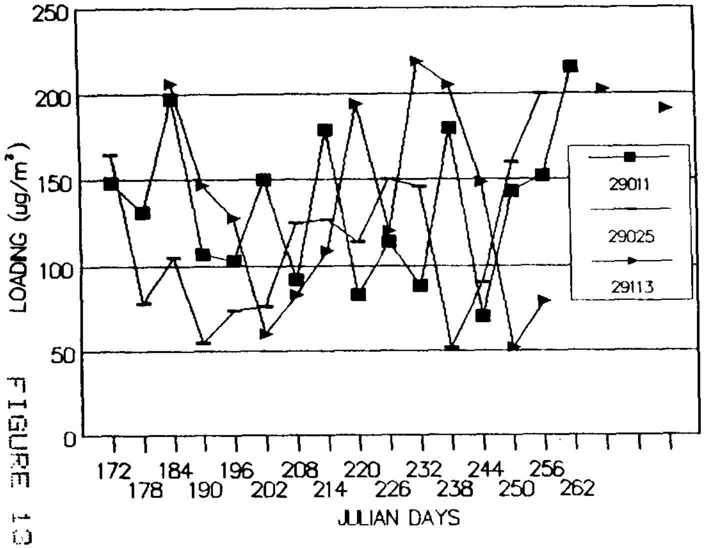
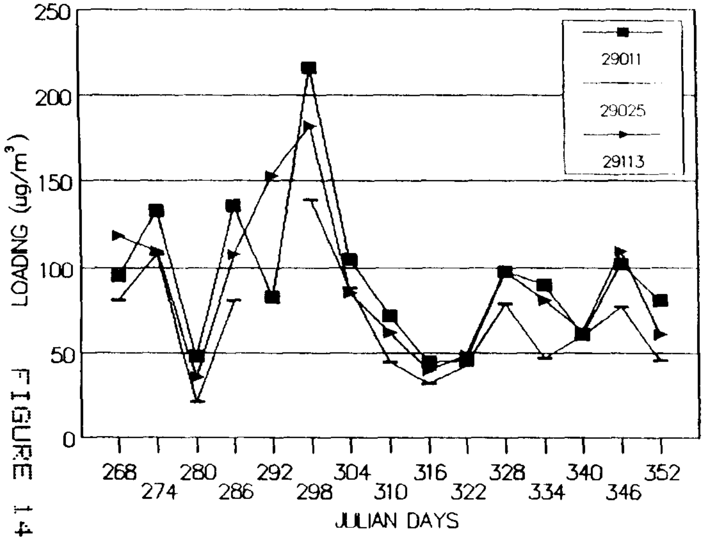


FIGURE 13



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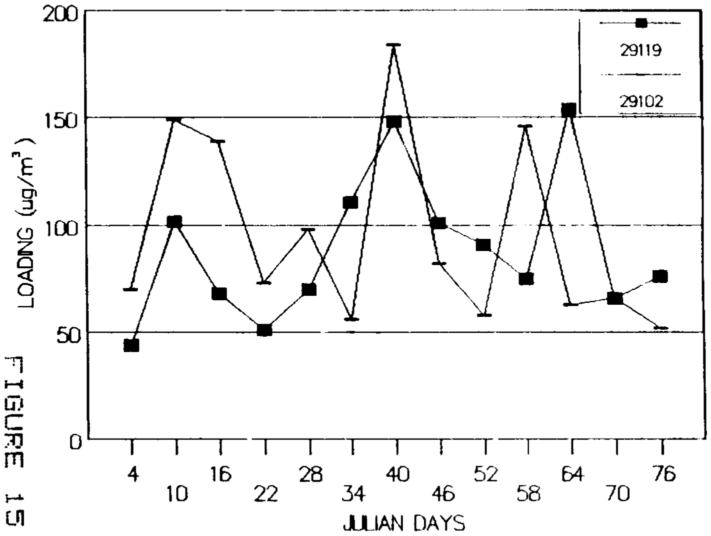

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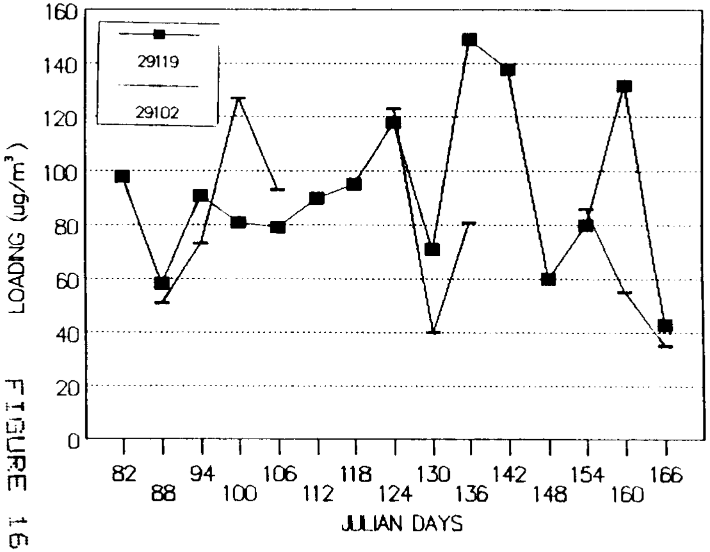


FIGURE 16

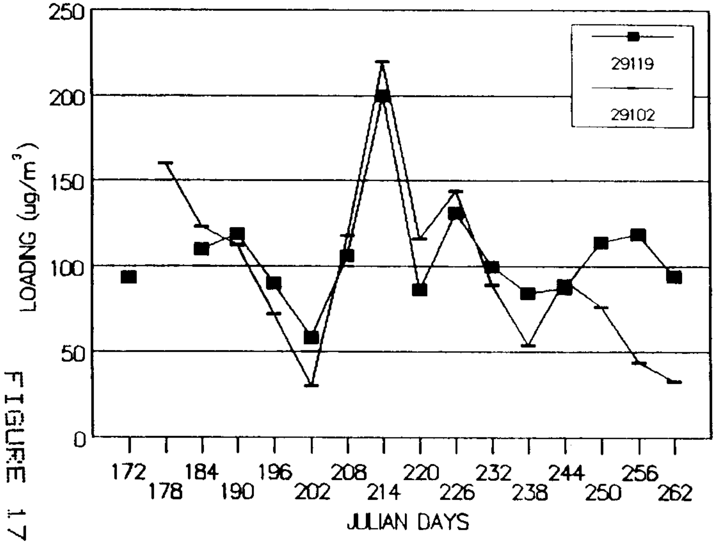


FIGURE 17

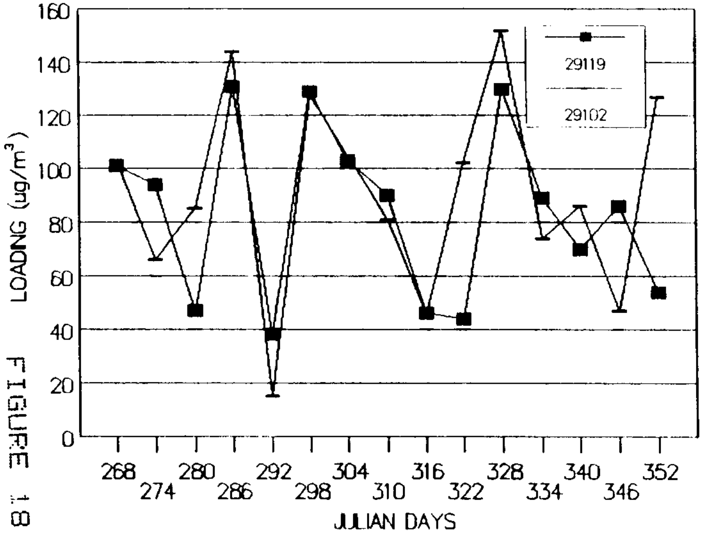


FIGURE 18

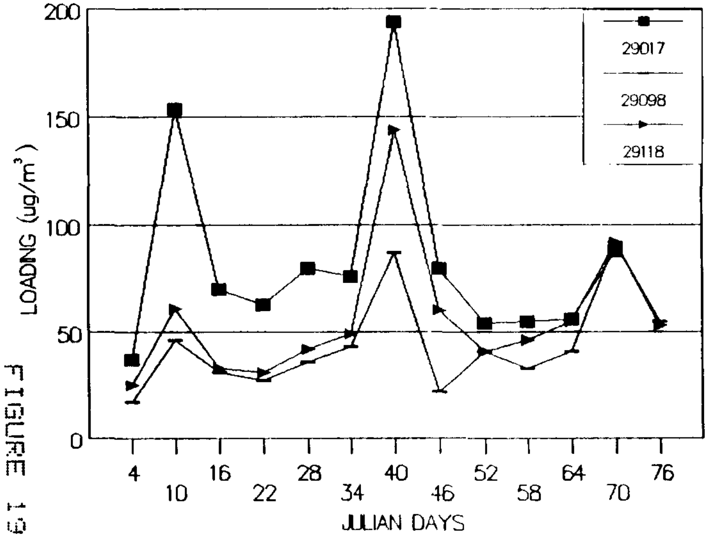


FIGURE 19

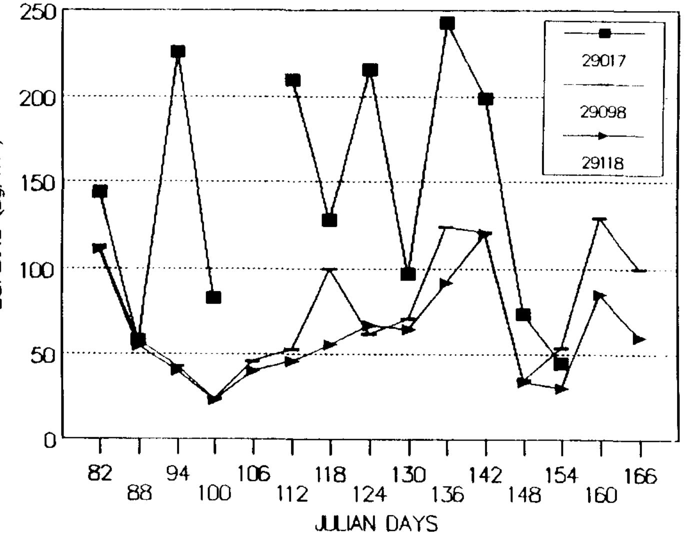


FIGURE 20

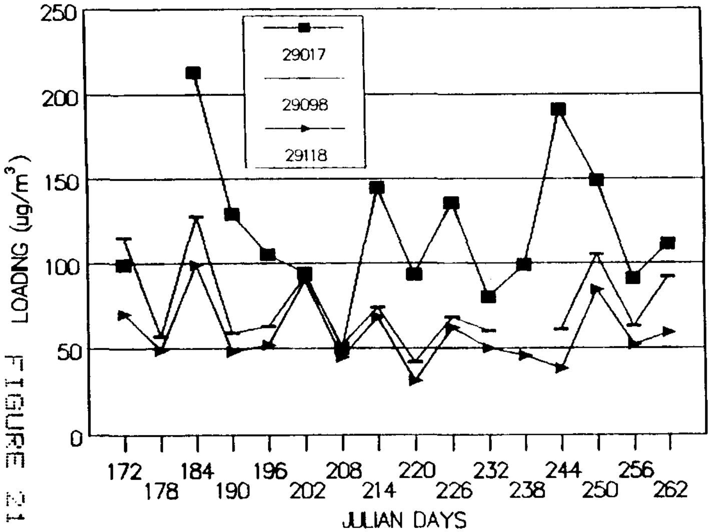


FIGURE 21

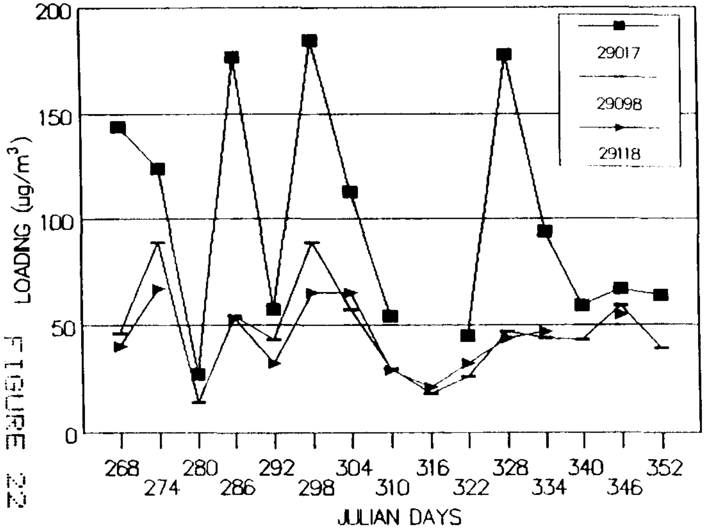


FIGURE 22

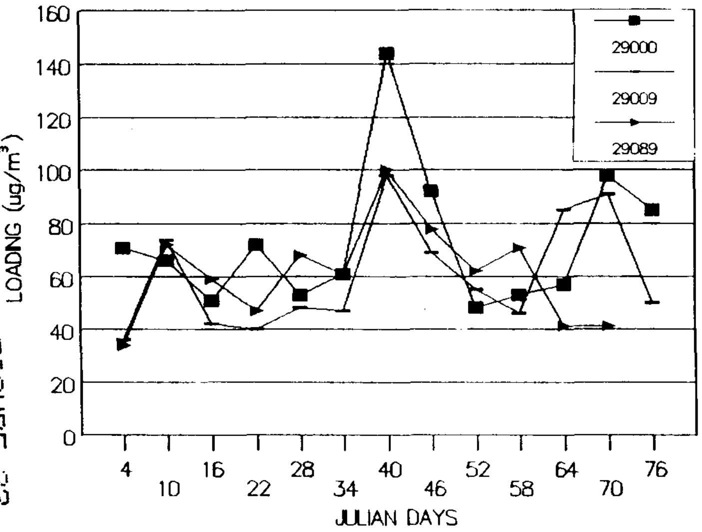


FIGURE 23

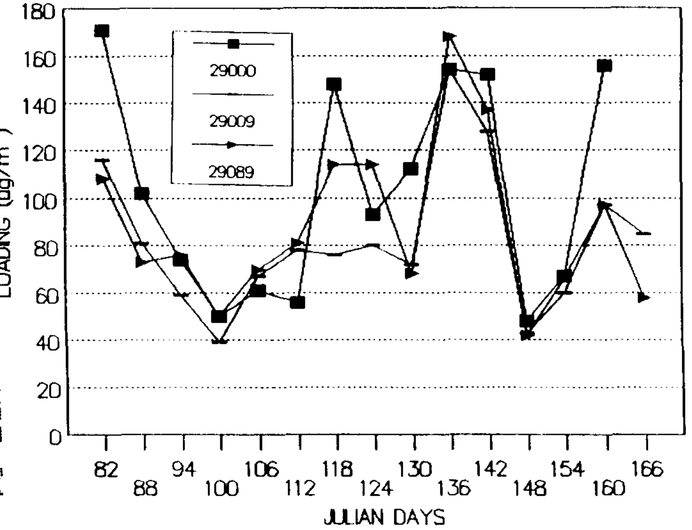


FIGURE 24

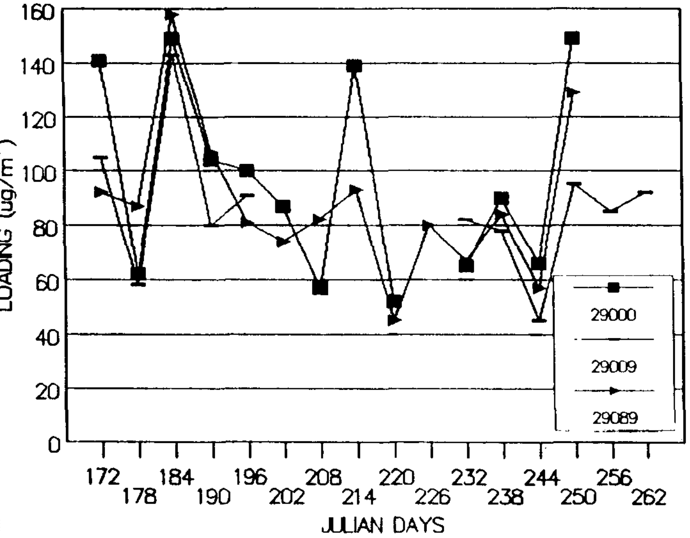


FIGURE 25

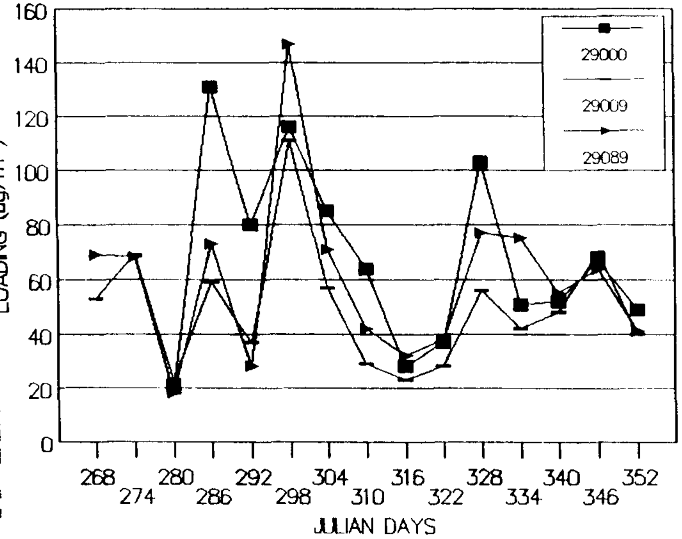


FIGURE 26

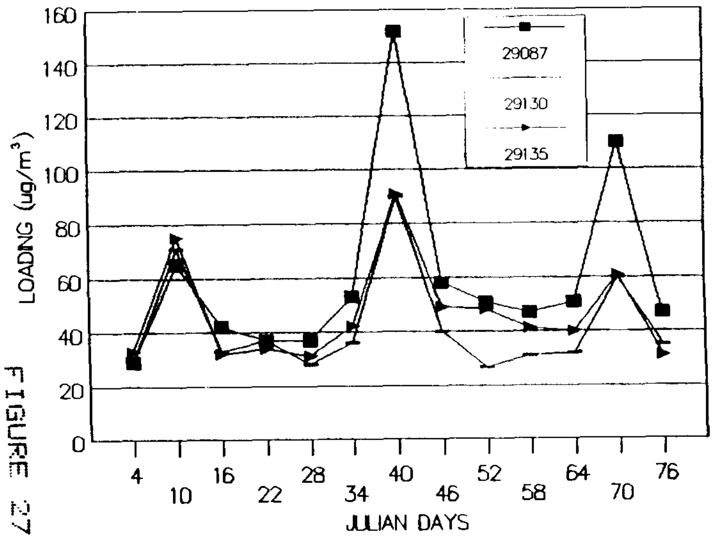


FIGURE 27

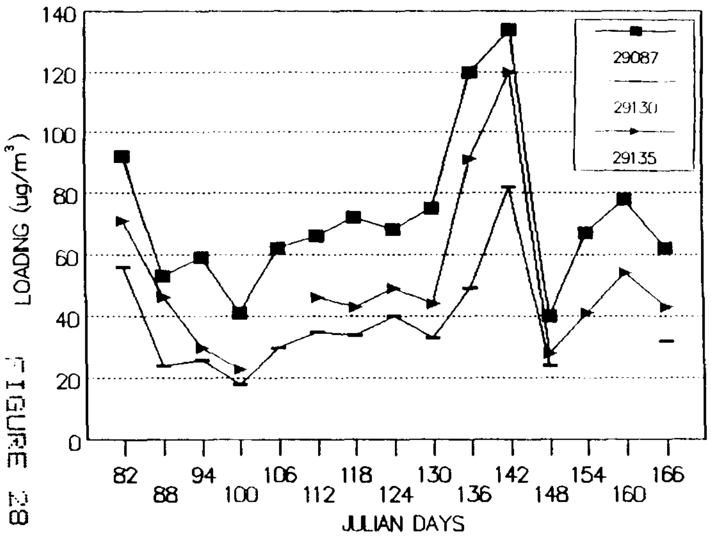


FIGURE 28

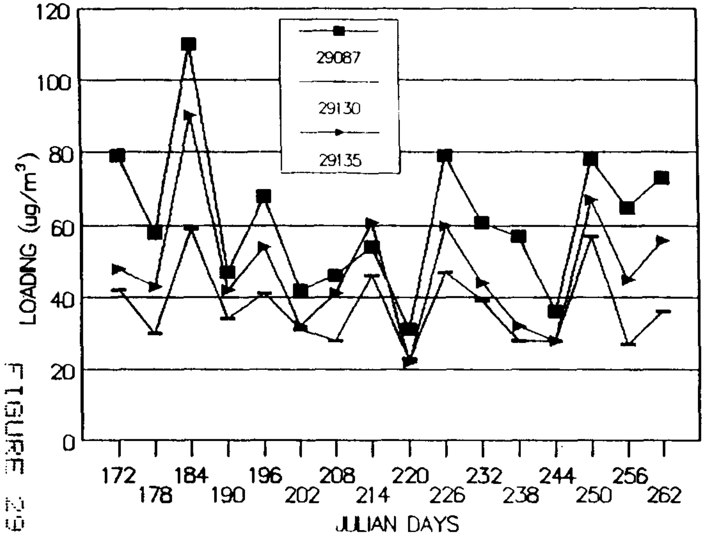


FIGURE 29

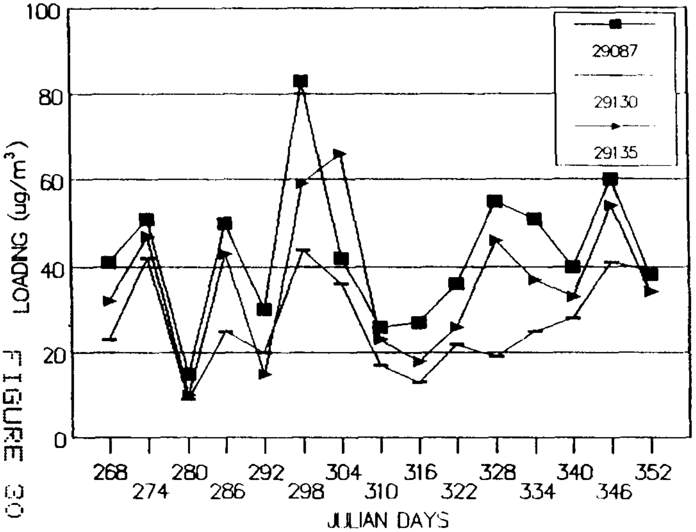


FIGURE 30

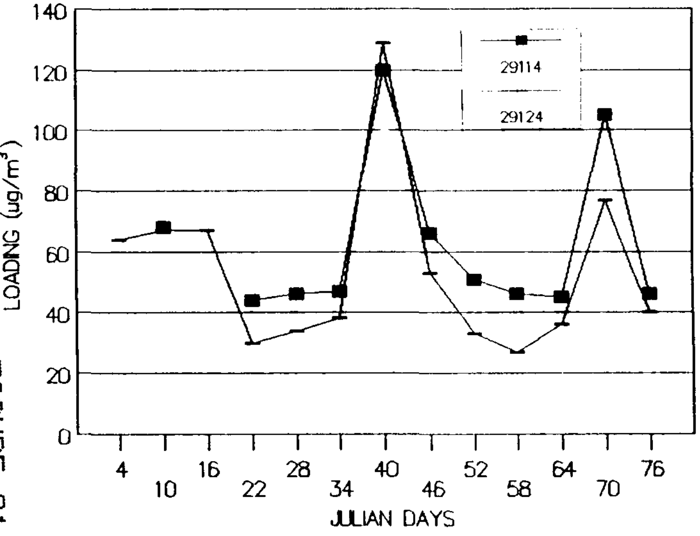


FIGURE 31

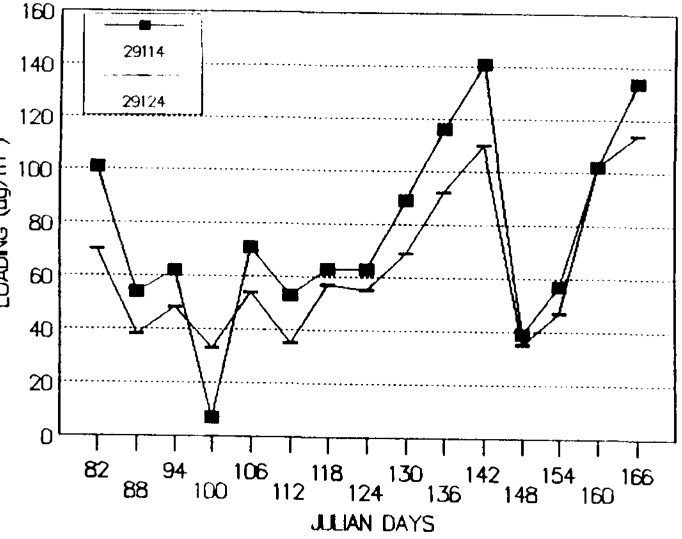


FIGURE 32

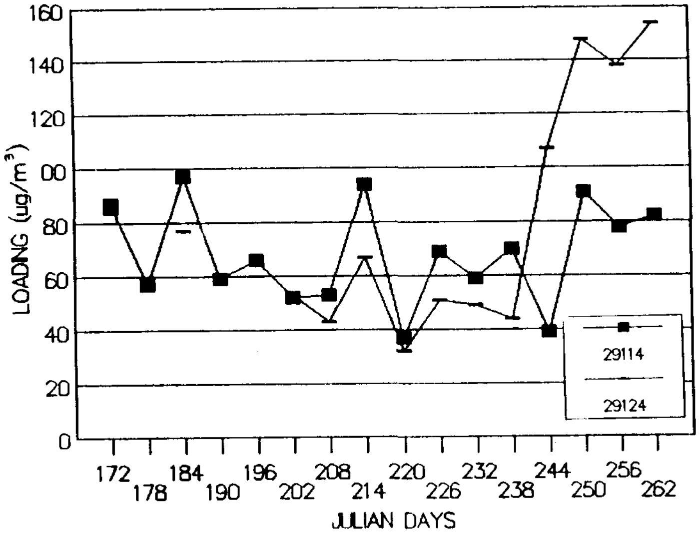


FIGURE 33

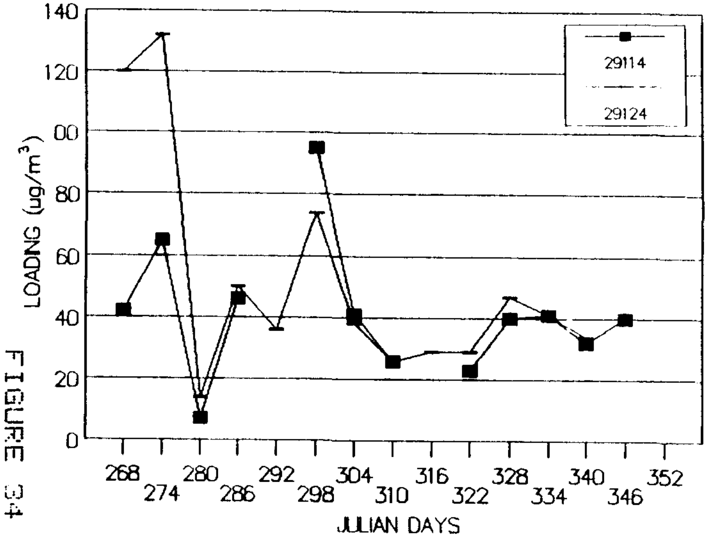


FIGURE 34

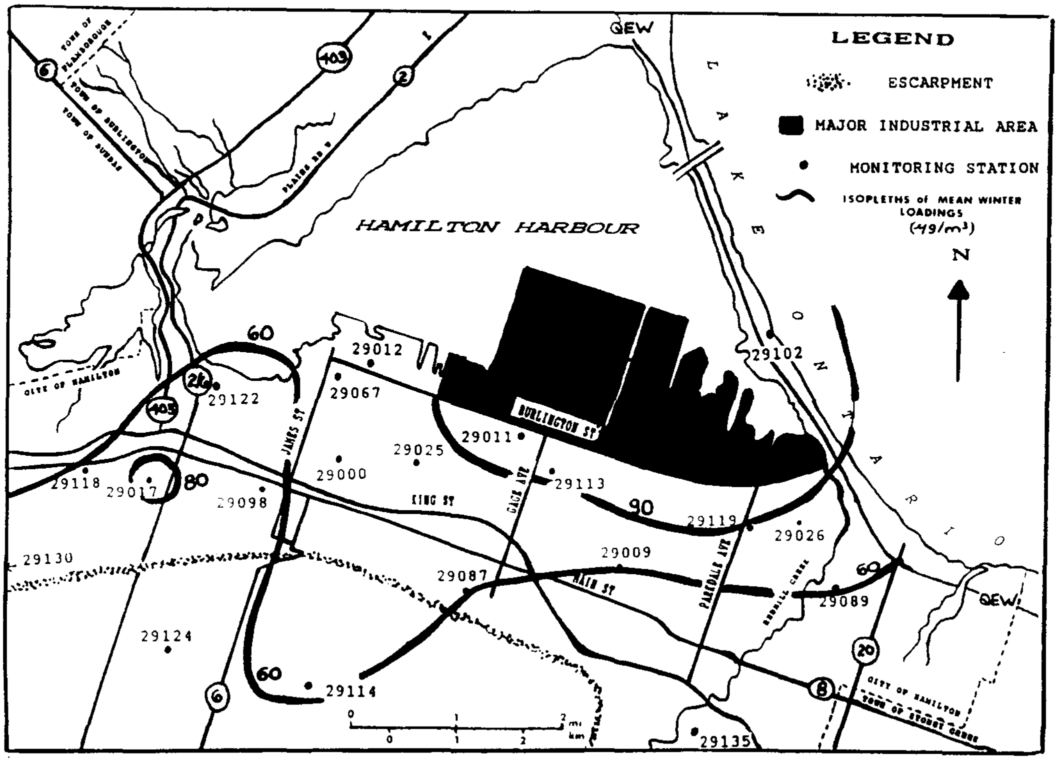
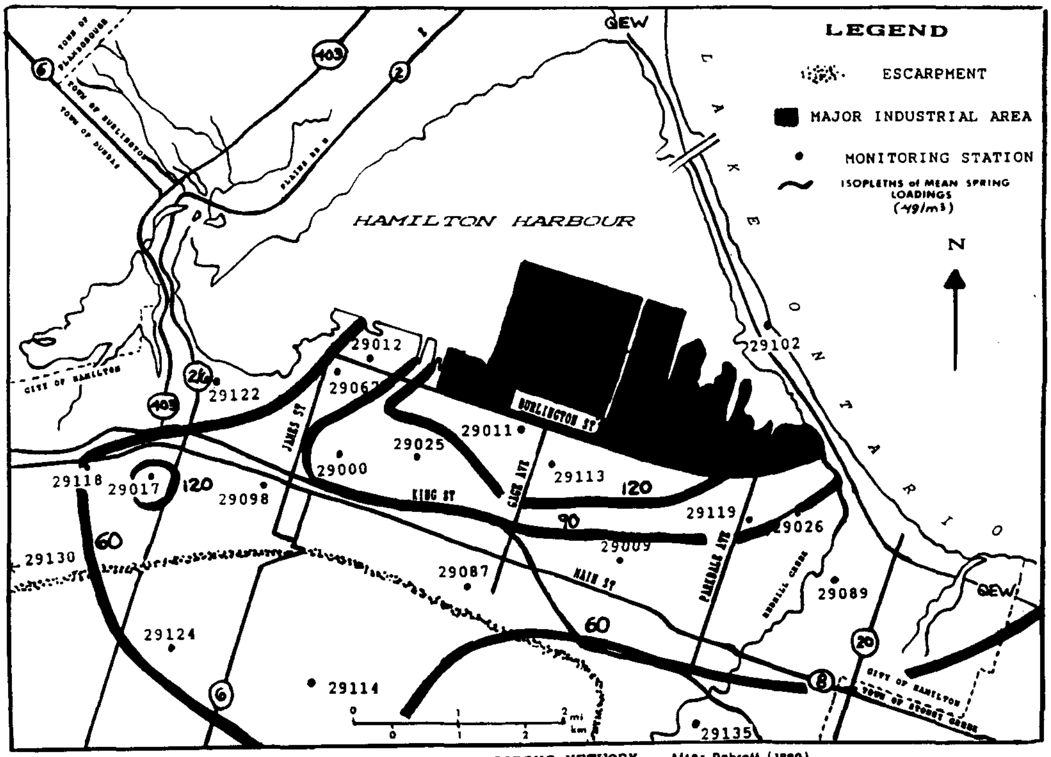


FIGURE 35

HAMILTON AIR MONITORING NETWORK
ISOPLETHS OF MEAN WINTER LOADINGS

After Dobroff (1990)



HAMILTON AIR MONITORING NETWORK
ISOPLETHS OF MEAN SPRING LOADINGS

After Dobroff (1990)

FIGURE 36

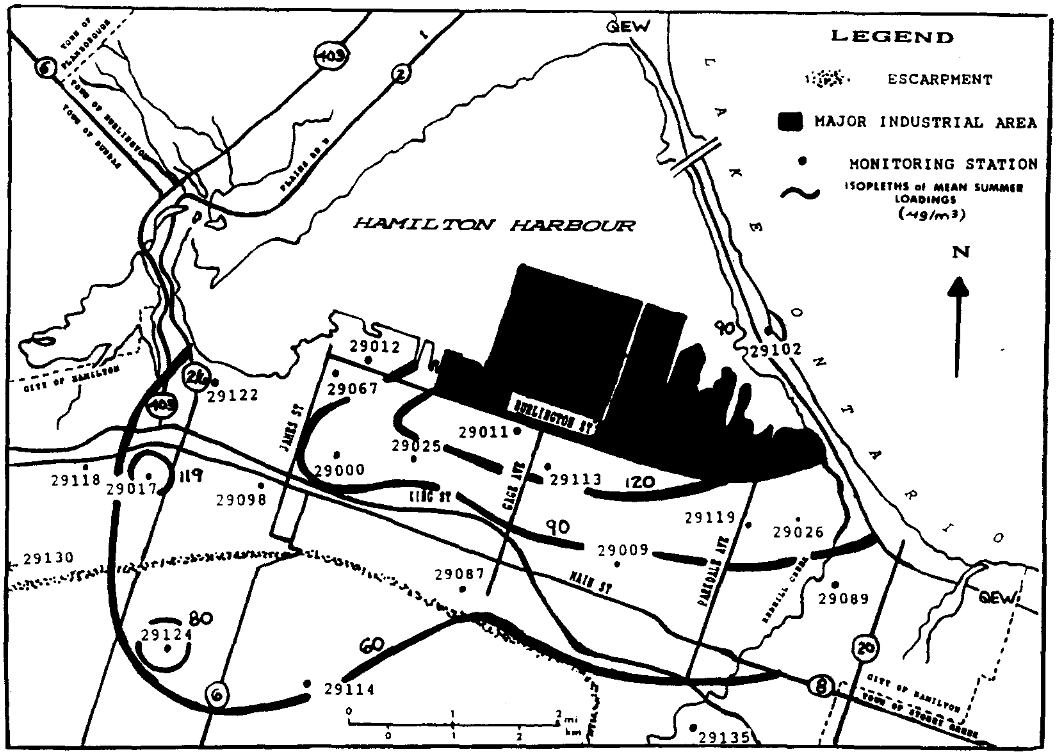


FIGURE 37

HAMILTON AIR MONITORING NETWORK
ISOPLETHS OF MEAN SUMMER LOADINGS

After Dobroff (1990)

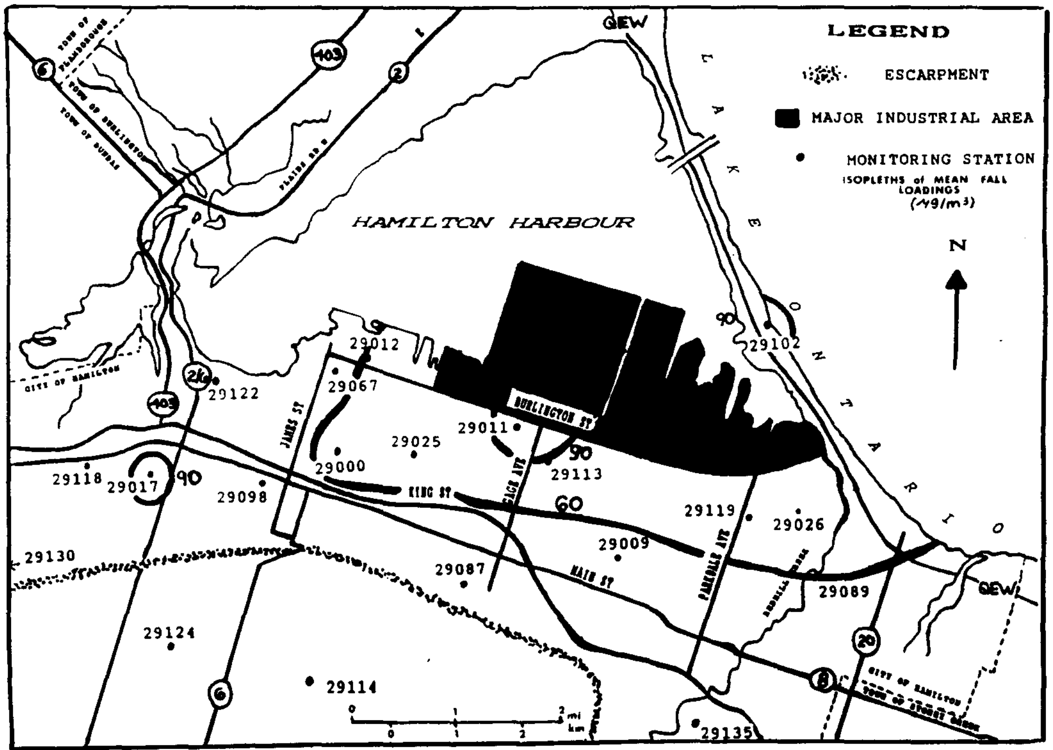


FIGURE 38

HAMILTON AIR MONITORING NETWORK
ISOPLETHS OF MEAN FALL LOADINGS

After Dobroff (1990)

CHAPTER 5 ANALYSIS

5.1 GRAPHICAL ANALYSIS

In observing the results from the previous section and from figures 3-34, prominent trends can be found. The spring season generally had the highest mean particulate loadings amongst the seasons, followed by the summer season. The lowest mean loadings were shared by the fall and winter seasons although in general the winter loadings were slightly greater than those measured in the fall season. Stations 29122 and 29102, both of which are located within short distances from major roadways, highways 2/6 and the QEW respectively, show minimum mean loadings in the spring season and maximum mean loadings in the summer period. This anomaly may be as a result of the summer construction period. During this period, transport use along these major thruways would be intensified, and fugitive dust emissions would likely be increased. Similarly, fugitive dust emissions would be more elevated during the winter due to the presence of road salt and sand which would increase particulate loadings at nearby measuring stations. This explanation cannot be deemed 'conclusive' as the particle fractionation of these emissions is unknown and therefore it is not clear if fugitive emissions actually reach the measuring site (i.e. the particle sizes are too large and would settle out almost immediately under the influence of gravity. Minimum loadings for winter, spring, summer and fall were found at stations 29122, 29114, 29135 and 29114 respectively. All of these stations (except station 29122) are located at the southern part of the city. Seasonal minimum values are located on the escarpment ('upper city') on two instances reflecting the inability of the wind to push pollutant above and beyond the Niagara escarpment. The low loading found at station 29135 may be due to the wind funnelling away from the site through the valley. Both stations are located at points furthest away from both the central business district and the major industrial sector. In looking at figures 3-34, it is apparent that some other mechanism other than the ones described earlier in the report, is in effect. One reason for the abnormally low reading at this station could be malfunctioning measuring equipment. Maximum readings were found at stations 29017, 29017, 29102, and 29011 for the winter, spring, summer and fall seasons respectively. Both stations 29102 and 29011 are within closest proximity to the industrial core, the former station is also near the QEW. Station 29017 is seen as a centre of high loadings in all seasons. This anomaly may be due to the wind funnelling through the Dundas Valley in conjunction with the station's proximity to highways 2, 6, 403, King, and Main streets.

Results from the descriptive analysis of the graphs show that in general, high wind speeds correspond to low particulate loadings and that low wind speeds correspond to high particulate loadings. This can be attributed to the settling velocity of the particles. Low wind speeds would tend to facilitate particulate deposition as higher wind speeds entrain a greater abundance of particles and particles having greater diameters. This relationship is also often coincidental with shifts in wind directions, namely shifts from the northern to the southern sector as described, yet this is not always the case. Based on findings from Dobroff (1990) and others, higher loadings would be anticipated when wind directions shift from the south sector to from the north sector. The present finding may be due to a latency effect whereby the effects of wind direction change are felt at a later date. Precipitation, based on primary analysis does not exhibit significant effects on atmospheric particulate loadings. Perhaps this is due to the lack of information on rainfall rates which may play an important role in particulate loadings (see Oke, 1987). The general trends discussed above cannot be deemed conclusive; there are occasions where high loadings are associated with high wind speeds rather than low wind speeds and other cases where high loadings are not associated with shifts in wind direction.

From isopleth maps of mean seasonal particulate loadings (figs. 35-38) it can be seen that seasonal influences do play an important role. This is seen on the mean loadings and on the spatial distribution and extent of particulate concentrations. Isopleths of particulate loadings are most extensive in the spring season where the 60 ug/m^3 isopleth extends beyond the Niagara escarpment, and the 90 ug/m^3 isopleth dips down to meet with King St. between James St. and Gage Ave. The 120 ug/m^3 isopleth line is only present in the spring and summer seasons. The isopleths shrink dramatically during the fall season. At this time, the 90 ug/m^3 isopleth does not extend beyond station 29113 near Gage Ave., and the 60 ug/m^3 isopleth is north of King St. In all seasons there is a 'displaced' isopleth centered about station 29017. Loadings begin to increase both in amount and in extent during the winter. The seasonal pattern may be explained by the joint effects of predominant wind directions and wind speeds (appendix). Highest mean loadings during the spring, were associated with low wind speeds (relative to the other seasons) coming from the north sector. High loadings, especially near the industrial core, are enhanced by the inability of the wind to effectively disperse the pollutants. The wind's direction would tend to push pollutants cityward rather than lakeward, as would southerly winds. High loadings in the summer result only from the influence of wind speed which lead to lower, spatially more isolated isopleths. High wind speeds from the south sector give rise to isopleth patterns observed for both the winter and fall seasons. Isopleths in each map exhibit pronounced lobes directed in a south-westerly orientation. Although these isopleth patterns may appear to be significant, they are likely merely a result of the location of particulate measuring stations which would lend themselves to this distribution.

5.1.1 SUMMARY

Graphical analysis has suggested possible influences on total suspended particulate loadings in the Hamilton region. It must be noted, however, that the apparent trend relating high wind speeds and directional wind shifts to low loadings cannot be described as an absolute measure of cause/effect. The evidence presented is inconclusive on this basis alone. Other factors such as local influences (fugitive and other unquantified emissions) and lack of measuring stations (for isopleth maps) may affect, or better explain the observed results.

5.2 STATISTICAL ANALYSIS

The principles behind regression analysis require that certain assumptions be understood:

1) That the given relationship is linear.
2) That the chosen sample is random.

The relationship used in the regression analysis is as follows:

$$PL = \alpha + \beta(WIND) + \gamma(DIR) + \theta(MTEMP) + \lambda(TPREC) + \zeta \quad [1]$$

Where PL represents the particulate loading at site, $\alpha, \beta, \gamma, \theta, \lambda, \zeta$, represent the regression coefficients for the regression constant, wind speed, wind direction, mean temperature, total precipitation and the residual respectively.

As seen in tables 5 & 6, R-squared statistics as related to measuring station locations, do not exemplify orderly spatial distributions. Actual loadings are best explained by meteorological parameters at station 29009 and least explained at station 29122. For all estimated coefficients, except for the constant, the associated standard error is usually greater than forty percent of the actual value. It is therefore questionable as to the accuracy and precision of the derived equations. The greater significance of the constants in the regression equations, shows that even without meteorological influences, there will be ambient particulate pollution. This is not surprising given that ambient particulate pollution is primarily dependent on emission amounts and rates, neither of which were considered in this analysis. T-statistics as seen on tables 7 & 8, reveal the statistical significance of the constant value, at the 95% confidence level ($\alpha = 0.05$) for most of the stations. At this confidence level, for most of the stations, the remaining parameters (eq [1]), appear to be non-significant. When the confidence level is decreased to the 90% level (α =0.01), the wind direction parameter becomes statistically significant for greater than fifty percent of the stations. This latter result supports past findings from other researchers, (Stewart and Matheson, 1967; Brooks and Salop, 1983; Bouchertall, 1989), showing the important role wind direction plays on atmospheric particulate loadings.

Coefficients for wind speed, mean temperature, and total precipitation are found to be statistically significant for only one-third of the nineteen stations examined.

Given the possibility that the first assumption of the regression may be invalid, a second regression was run. This regression kept the dependent variable in a linear format while changing the independent variables to a logarithmic scale. Results from this regression reveal the possibility of a linear-logarithmic (lin-log) relationship between the dependent and independent variables. This is shown through improved R-squared values for certain stations (29011, 29012, 29025, 29087, 29089, 29098, 29102, 29113, 29118, 29119, 29122, and station 29124). The reasoning behind this outcome is unclear, as the distribution shows no pattern. Standard errors for the coefficients are greater in the lin-log case than in the straight linear case.

TABLE 5

TABLE OF ESTIMATED COEFFICIENTS

Linear Regression

DEPENDENT VARIABLE — INDEPENDENT VARIABLES

d.f. = 32

SITE #		α	β	γ	θ	λ
29000	Est.Coeff	87.796	-0.06508	-2.5898	1.2407	0.32193
	Std.Err.	17.076	1.1959	1.0768	0.61902	0.22263
	T ratio	5.1416	-0.5486	-2.405	2.0044	1.446
	R-squared	0.3154				
29009	Est.Coeff	82.879	-1.5847	-1.6943	1.6331	0.9949
	Std.Err.	18.838	1.3193	1.188	0.68291	0.24561
	T ratio	4.3995	-1.2012	-1.4262	2.3913	4.0509
	R-squared	0.4973				
29011	Est.Coeff	125.78	-1.9811	-1.9084	0.58741	-0.18774
	Std.Err.	22.444	1.5719	1.4154	0.81365	0.29263
	T ratio	5.6041	-1.2603	-1.3483	0.72194	-0.64155
	R-squared	0.2751				
29012	Est.Coeff	81.114	-0.07808	0.09338	1.3967	0.31779
	Std.Err.	23.655	1.6567	1.4917	0.85753	0.30841
	T ratio	3.429	-0.47133	0.0626	1.6288	1.0304
	R-squared	0.1557				
29017	Est.Coeff	111.54	-1.7659	-3.2693	0.67837	0.53009
	Std.Err.	26.203	1.8351	1.6524	0.94991	0.34163
	T ratio	4.2567	-0.96226	-1.9785	0.71415	1.5516
	R-squared	0.1861				
29025	Est.Coeff	103.74	-1.9857	-1.6321	0.10004	-0.05235
	Std.Err.	16.634	1.165	1.049	0.60301	0.21687
	T ratio	6.2366	-1.7045	-1.5559	0.16589	-0.24139
	R-squared	0.2496				
29067	Est.Coeff	79.347	-0.3276	-1.1037	-0.38016	0.26895
	Std.Err.	15.566	1.0901	0.9816	0.56428	0.20294
	T ratio	5.0975	-1.2178	-1.1244	-0.6737	1.3252
	R-squared	0.1142				
29087	Est.Coeff	74.65	-1.2338	-0.68566	0.71389	0.11721
	Std.Err.	17.141	1.2005	1.0809	0.62139	0.22348
	T ratio	4.355	-1.0277	-0.63431	1.1489	0.52448
	R-squared	0.1347				
29089	Est.Coeff	101.94	-2.5881	-0.92065	0.49353	0.27384
	Std.Err.	18.625	1.3044	1.1745	0.67518	0.24283
	T ratio	5.4732	-1.9841	-0.78386	0.73096	1.1277
	R-squared	0.2201				
29098	Est.Coeff	77.691	-1.7391	-1.2697	1.7602	0.67448
	Std.Err.	23.551	1.6494	1.4851	0.85375	0.30705
	T ratio	3.2989	-1.0544	-0.85491	2.0617	2.1966
	R-squared	0.3074				
29102	Est.Coeff	65.147	2.9004	-2.2207	0.90222	0.25498
	Std.Err.	20.468	1.4335	1.2907	0.742	0.26686
	T ratio	3.1829	2.0233	-1.7205	1.2159	0.9555
	R-squared	0.1985				

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

TABLE 5 (CONT'D)

TABLE OF ESTIMATED COEFFICIENTS

DEPENDENT VARIABLE SITE #		INDEPENDENT VARIABLES d.f. = 32 α	β	γ	θ	λ
29113	Est.Coeff	132.18	-3.6892	-2.4676	0.123	0.14505
	Std.Err.	21.75	1.5233	1.3716	0.78849	0.28358
	T ratio	6.0771	-2.4219	-1.799	0.156	0.51148
	R-squared	0.2883				
*29114	Est.Coeff	57.487	-1.9546	-1.4049	0.80203	0.35411
	Std.Err.	13.457	0.57991	1.0114	0.51389	0.19515
	T ratio	4.272	-0.33706	-1.389	1.5607	1.8146
	R-squared	0.1734				
29118	Est.Coeff	64.396	-0.13858	0.44178	1.1383	-0.23089
	Std.Err.	21.706	1.5202	1.3688	0.7869	0.28301
	T ratio	2.9667	-0.09116	0.32274	1.4465	-0.81585
	R-squared	0.1183				
29119	Est.Coeff	102.85	-1.647	-2.1172	-0.15816	-0.04261
	Std.Err.	18.306	1.2821	1.1544	0.66364	0.23868
	T ratio	5.6183	-1.2846	-1.8339	-0.23833	-0.17854
	R-squared	0.234				
29122	Est.Coeff	74.168	-1.4551	-0.58044	-0.28266	0.0941
	Std.Err.	19.989	1.3999	1.2605	0.72462	0.26061
	T ratio	3.7105	-1.0394	-0.46048	-0.39008	0.36109
	R-squared	0.0432				
*29124	Est.Coeff	77.181	-1.3094	1.1376	0.39498	-0.33898
	Std.Err.	29.736	1.2815	2.235	1.1356	0.43123
	T ratio	2.5956	-1.0218	0.50898	0.34783	-0.78608
	R-squared	0.0703				
29130	Est.Coeff	-18.613	5.9479	-2.3367	1.8401	0.45316
	Std.Err.	30.393	2.1286	1.9166	1.1018	0.39626
	T ratio	-0.61242	2.7943	-1.2192	1.6701	1.1436
	R-squared	0.228				
29135	Est.Coeff	121.86	-3.1088	5.3093	1.3644	-1.2676
	Std.Err.	51.55	3.6103	3.2508	1.8688	0.67211
	T ratio	2.3639	-0.86109	1.6332	0.73013	-1.886
	R-squared	0.1511				

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

* For these stations, wind values from the upper escarpment were used

TABLE 6

TABLE OF ESTIMATED COEFFICIENTS

Log-Linear Regression

DEPENDENT VARIABLE SITE #		INDEPENDENT VARIABLES d.f. = 32				
		α	β	γ	θ	λ
29000	Est.Coeff	126.28	-21.057	-6.1765	7.3011	-0.61268
	Std.Err.	38.116	14.081	10.729	5.5439	5.9757
	T ratio	3.313	-1.4955	-0.5757	1.317	-0.10253
	R-squared	0.2972				
29009	Est.Coeff	133.82	-30.557	17.764	9.7671	-1.4393
	Std.Err.	50.21	18.548	14.133	7.3029	7.8716
	T ratio	2.6652	-1.6474	1.257	1.3374	-0.18285
	R-squared	0.2642				
29011	Est.Coeff	191.27	-37.176	-9.2845	1.8561	-5.8443
	Std.Err.	45.568	16.834	12.826	6.6277	7.1439
	T ratio	4.1974	-2.2085	-0.72388	0.28005	-0.81808
	R-squared	0.3844				
29012	Est.Coeff	86.633	-11.933	22.921	15.839	-7.1316
	Std.Err.	49.884	18.428	14.041	7.2555	7.8205
	T ratio	1.7367	-0.64753	1.6324	2.1831	-0.91191
	R-squared	0.2265				
29017	Est.Coeff	178.94	-36.996	1.3094	2.9722	-6.032
	Std.Err.	57.829	21.363	16.277	8.411	9.0661
	T ratio	3.0943	-1.7318	0.08044	0.35337	-0.66534
	R-squared	0.1832				
29025	Est.Coeff	155.15	-30.677	-9.0187	-1.1816	-2.4262
	Std.Err.	34.701	12.819	9.7674	5.0472	5.4403
	T ratio	4.4709	-2.393	-0.92335	-0.23411	-0.44597
	R-squared	0.3271				
29067	Est.Coeff	121.94	-22.657	0.54044	-4.6389	-1.1408
	Std.Err.	34.589	12.778	9.7359	5.0309	5.4228
	T ratio	3.5254	-1.7731	0.05551	-0.92207	-0.21038
	R-squared	0.00989				
29087	Est.Coeff	94.108	-16.093	8.5141	6.676	-6.29155
	Std.Err.	36.385	13.441	10.241	5.292	5.7042
	T ratio	2.5865	-1.1973	0.83135	1.2615	-1.103
	R-squared	0.1967				
29089	Est.Coeff	174.08	-41.909	3.9662	-0.84256	-1.5133
	Std.Err.	40.454	14.945	11.387	5.8839	6.3422
	T ratio	4.303	-2.8043	0.34832	-0.1432	-0.2386
	R-squared	0.2419				
29098	Est.Coeff	107.26	-24.842	16.861	13.954	-3.1209
	Std.Err.	54.974	20.309	15.474	7.9959	8.6186
	T ratio	1.9512	-1.2232	1.0897	1.7451	-0.36211
	R-squared	0.2225				

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

TABLE 6 (CONT'D)

TABLE OF ESTIMATED COEFFICIENTS

DEPENDENT VARIABLE **INDEPENDENT VARIABLES**

d.f. = 32

SITE #		α	β	γ	θ	λ
29102	Est.Coeff	13.203	32.744	4.6569	10.384	-6.9781
	Std.Err.	44.576	16.467	12.547	6.4835	6.9884
	T ratio	0.29618	1.9884	0.37116	1.6016	-0.99852
	R-squared	0.2168				
29113	Est.Coeff	238.75	-59.938	-22.594	-5.5956	5.1703
	Std.Err.	44.729	16.524	12.59	6.5058	7.0125
	T ratio	5.3376	-3.6274	-1.7946	-0.8601	0.7373
	R-squared	0.3799				
*29114	Est.Coeff	76.87	-0.08745	-9.4062	5.9487	-2.2732
	Std.Err.	23.779	10.718	7.5418	4.3362	5.2265
	T ratio	3.2327	-0.00816	-1.2472	1.3719	-0.43493
	R-squared	0.1123				
29118	Est.Coeff	21.058	11.892	25.843	15.465	-16.91
	Std.Err.	43.29	15.992	12.185	6.2964	6.7868
	T ratio	0.48643	0.74359	2.1209	2.4562	-2.4916
	R-squared	0.2775				
29119	Est.Coeff	141.61	-23.165	-13.218	-2.8926	-1.8334
	Std.Err.	39.242	14.497	11.045	5.7076	6.1522
	T ratio	3.6085	-1.5979	-1.1967	-0.50679	-0.29801
	R-squared	0.2748				
29122	Est.Coeff	99.825	-18.193	5.7536	-1.128	-4.0794
	Std.Err.	43.682	16.137	12.295	6.3534	6.8482
	T ratio	2.2853	-1.1274	0.46796	-0.17754	-0.59569
	R-squared	0.0586				
*29124	Est.Coeff	80.573	21.558	-12.98	7.1149	-12.603
	Std.Err.	49.946	22.514	15.841	9.108	10.978
	T ratio	1.6132	0.95755	-0.81938	0.78117	-1.148
	R-squared	0.0979				
29130	Est.Coeff	-43.862	37.599	-14.732	11.29	7.5974
	Std.Err.	71.365	26.364	20.087	10.38	11.188
	T ratio	-0.61462	1.4262	-0.73342	1.0877	0.67905
	R-squared	0.123				
29135	Est.Coeff	87.835	-7.4925	19.535	19.411	-12.824
	Std.Err.	118.43	43.75	33.335	17.225	18.567
	T ratio	0.74167	-0.17126	0.58603	1.1269	-0.69067
	R-squared	0.0769				

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

* For these stations, wind values from the upper escarpment were used

T-ratios are more significant for a greater number of stations, for wind speed, at both the 90% and the 95% confidence levels in the lin-log case, than in the straight linear case. Greater than fifty percent stations reveal wind speed as a significant parameter. This supports Simpson and Miles' (1990) findings which related the percentiles of wind speed to particulate loadings. Precipitation coefficients are less frequently significant, while the constant and temperature variables have similar frequencies in both the linear and in the lin-log case. The drastic reduction in significance frequencies found for the wind direction variable is due to the fact that this variable was inputted into the program as a dummy variable, 1, representing wind coming from the northern sector, and 0, representing wind coming from the southern sector. For this variable as well as for other observations, there was the problem of undefined values (i.e. generating log values from negative numbers). In these cases the number was set to zero, giving rise to inaccurate results.

The log-log regression analysis did not add to the above findings; R-square statistics were found to be zero in all cases. Lag factors did not have a significant effect on the regression equation. This was probably due to the nature of the data set, given that loadings were measured on a six day cycle. Loadings may have been influenced by ambient pollution levels from the day prior to measurement

TABLE 7

SIGNIFICANCE FINDINGS FOR T-RATIOS OF COEFFICIENTS
(linear regression)

STATION #	α	β	γ	θ	λ
29000	S	NS	S	S	NS
29009	S	NS	NS	S	S
29011	S	NS	NS	NS	NS
29012	S	NS	NS	NS	NS
29017	S	NS	S	NS	NS
29025	S	S	NS	NS	NS
29067	S	NS	NS	NS	NS
29087	S	NS	NS	NS	NS
29089	S	S	NS	NS	NS
29098	S	NS	NS	S	S
29102	S	S	S	NS	NS
29113	S	S	S	NS	NS
29114	S	NS	NS	NS	S
29118	S	NS	NS	NS	NS
29119	S	NS	S	NS	NS
29122	S	NS	NS	NS	NS
29124	S	NS	NS	NS	NS
29130	NS	S	NS	NS	NS
29135	NS	NS	NS	NS	S

d.f. = 32

t-critical = 1.699

$\alpha = 0.05$

Ho = coefficient is not significant

Ha = coefficient is significant

if t-statistic > t-critical,

reject the Null hypothesis

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

TABLE 8

SIGNIFICANCE FINDINGS FOR T-RATIOS OF COEFFICIENTS
(linear-log regression)

STATION #	α	β	γ	θ	λ
29000	S	NS	S	S	S
29009	S	NS	S	S	S
29011	S	NS	S	NS	NS
29012	S	NS	NS	S	NS
29017	S	NS	S	NS	S
29025	S	S	S	NS	NS
29067	S	NS	NS	NS	S
29087	S	NS	NS	NS	NS
29089	S	S	NS	NS	NS
29098	S	NS	NS	S	S
29102	S	S	S	NS	NS
29113	S	S	S	NS	NS
29114	S	NS	S	S	S
29118	S	NS	NS	S	NS
29119	S	S	S	NS	NS
29122	S	NS	NS	NS	NS
29124	S	NS	NS	NS	NS
29130	NS	S	NS	S	NS
29135	S	NS	S	NS	S

d.f. = 32

t-critical = 1.310

$\alpha = 0.01$

Ho = coefficient is not significant

Ha = coefficient is significant

if t-statistic > t-critical,

reject the Null hypothesis

α = constant
β = coefficient for wind speed
γ = coefficient for wind direction
θ = coefficient for mean temperature
λ = coefficient for total precipitation

but loadings from six days before would likely exhibit negligible effects, due to wind dispersal mechanisms.

5.2.1 SUMMARY

It can be concluded from the analysis presented above that wind speeds and wind direction are frequently correlated with particulate loadings, but that the degree and direction of this correlation differ, depending on the station being studied. Regression analyses reveal the distinct nature of each measuring station; different equations were derived for each measuring station. Results from the coefficient of determination show that neither the linear regression, nor the lin-log regression, nor the log-log regression explain the relationship between the dependent and the independent variables with great precision. It follows that the first assumption may have beeb violated, and that a non-linear relationship may well explain the dependence of particulate loading on wind speed, wind direction, mean temperature, and total precipitation.

CHAPTER 6 CONCLUSIONS

6.1 CONCLUSIONS OF THE STUDY

Past studies in Hamilton and other regions have shown that wind direction plays a major role in influencing atmospheric particulate loadings. Graphical analyses from this study have supported past findings by other authors. Wind coming from the northern sector, the predominant wind direction during the spring season, is shown to increase mean particulate loadings, and to aerially extend mean particulate isopleths in the Hamilton region. The statistical relationship between particulate loadings and meteorological parameters (wind speed, wind direction, mean temperature and total precipitation) on linear, linear-log and log-log scales are deemed weak and inconclusive. Results have shown that most parameter coefficients, except for the constant variable and the wind direction parameter in the straight linear regression, and the constant variable and the wind speed parameter in the linear-log regression, are not statistically significant. Results have also shown that different regression equations are found for each monitoring station tested. It follows from this that a non-linear correlation may well explain the dependence of particulate loading on wind speed, wind direction, mean temperature and total precipitation, and that source, (point and fugitive emissions), and other factors play important roles in this complex relationship.

6.2 AREAS FOR FUTURE RESEARCH

Inconclusive findings from this research stresses the need for further studies on the relationship between TSP loadings and meteorological parameters. It is suggested that where possible, analyses should be done to account for the influence of mid-day, and frequent diurnal wind shifts, and that ambient and point source emissions be considered as part of the analysis. Despite incomplete data on emissions and the effect long range transport has on measured loadings, this additional data may narrow the error found in the derived relationships. Daily data, (if available), would allow for the evaluation of the role of lag factors on empirical relationships.

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APPENDIX

TABLE 9

1989 HI-VOL DATA SUMMARY HAMILTON

	DAY	WIND SPD [below esc] (km/hr)	PREDOM. DIRECTn *	WIND SPD [above esc] (km/hr)	mean temp.	PREDOM. DIRECTn	TOTAL PRECIPn (mm)
JAN 4	4	14		14.5	-17.2	N	0
	10	15	0	24.3	-3.3	SSW	0
	16	13	0	21.8	-1.5	WSW	0.2
	22	17	0	25.9	-1.2	SW	0
	28	15	0	27.7	2	WSW	0
	34	11	1	16.2	-9.1	N/NNW	0
	40	20	0	34.2	-12.4	W	0.5
	46	11	1	14.2	-0.8	ENE	0.4
	52	12	1	15.5	-0.2	WNW	3.6
	58	10		13.1	-5.7	W	0.8
	64	15		18.3	-2.6	NNE	4.7
	70	6		11.2	1.7	ENE/NE	0
	76	22	1	29.5	-2.1	ENE	18.2
MAR. 21	82	9		14.4	-1.3	ENE	0
	88	16	1	20.5	7.1	ENE	0
	94	10		19.9	7.4	ENE	6.8
	100	17		26.5	-3.8	W	0
	106	8		12.3	6.4	SSW	0
	112	11	1	14.8	3.4	N	0
	118	12	1	19.8	5.6	ENE	0
	124	9	0	16	10.4	SW/SSW	0
	130	7	1	20.6	8.2	ENE	6.7
	136	3	1	11.2	16.2	NE	0.2
	142	9	1	13.2	16.1	WNW	0
	148	9		14.3	11.5	WNW/SSW	0
	154	9	0	15.2	18.3	WSW	5.5
	160	5	1	13.4	17.1	ENE	5.2
	166	6	1	12.4	13.5	ENE	1.2
JUNE 21	172	4	1	10.6	15	ENE	2
	178	9		15	22.6	W	0
	184	6		7.4	22.8	W	0
	190	9	0	11.6	20.5	SW	0
	196	8		7.7	15.5	NW	0
	202	11	1	21.2	19.6	ENE	0
	208	9	0	12.6	22.5	SW	3.5
	214	13	0	16.5	23.2	SW	0
	220	9		12.3	12.8	W	0
	226	7	0	10.1	21.6	SW	0
	232	10	0	12	19.1	SSW	0
	238	5	1	9	16.5	ENE	0
	244	10		18.3	19.5	SSW/SW	30.4
	250	4	0	6	21.7	S	0
	256	10	1	13	14.2	NNE	0.5
	262	8	1	12.4	17.5	ENE	0

1989 HI-VOL DATA SUMMARY HAMILTON

	DAY	WIND SPD [below esc] (km/hr)	PREDOM. DIRECTn	WIND SPD [above esc] (km/hr)	mean temp.	PREDOM. DIRECTn	TOTAL PRECIPn (mm)
SEPT. 21	268	6	0	10.3	10.5	SSW	0
	274	5		10.9	14	SSE	0
	280	14	1	22.9	6.9	W	0.8
	286	7		10.1	12.8	SW/WSW	0
	292	31	1	40.4	3.4	ENE	9.5
	298	3	0	8	14.5	SW	0
	304	10	0	16.9	13	S	8
	310	16	0	25.3	8.4	W	2.7
	316	12		17.5	2.7	W	0
	322	16	0	25.7	-5.4	W	3.2
	328	13	0	20.8	-2.7	WSW	0
	334	15		31.3	-2.7	WSW	0.6
	340	12		16.3	-3.4	SW	1.1
	346	7	1	7.8	-10	N	2.2
	352	14	0	19.5	-12.5	WSW	0
DEC. 21	358	13	0	21	-14.2	SW	0.2
	364	20	1	27.6	-6.7	NE	0.9

* 0 = Wind due North (i.e. from the Southern sector)
* 1 = Wind due South (i.e. from the Northern sector, blowing citywards)

Directions include only days where the wind was coming from a given sector for at least 90% of the 24 hr period (i.e. 22 of 24 hrs., including calm periods and periods from the East and West)

TABLE 10

TOTAL SUSPENDED PARTICULATE (ug/m^3)

DAY	JULIAN DAY	29000	29009	29011	29012	29017	29025	29067	29087	29089	29098
JAN 4	4	71	36	55	31	37	29	27	29	34	17
	10	66	74	103	79	154	93	73	65	72	46
	16	51	42	69	54	70	53	41	42	59	31
	22	72	40	49	39	63	74	36	37	47	27
	28	53	48	73	58	80	64	58	37	68	36
	34	61	47	95	48	76	52	67	53	61	43
	40	144	98	154	159	194	153	168	152	100	87
	46	92	69	136	67	80	117	75	58	78	22
	52	48	55	79	45	54	63	59	51	62	41
	58	53	46	83		55	67	41	47	71	33
	64	57	85	119	54	56	58	56	51	41	41
	70	98	91	146	56	88	130	57	110	41	92
	76	85	50	129	74		98	54	47		55
MAR. 21	82	171	116	251	77	144	165	72	92	108	113
	88	102	81	196	66	58	78	52	53	73	58
	94	74	59	94	52	226	105	41	59	76	43
	100	50	39	79	52	83	55	55	41	50	24
	106	61	67	88	63		74	58	62	70	46
	112	56	78	149	75	210	76		66	81	53
	118	148	76	189	69	128	125	39	72	114	100
	124	93	80	146	86	216	127	68	68	114	62
	130	112	72	133	65	97	114	55	75	68	71
	136	154	154	246	158	243	150	98	120	168	124
	142	152	128	179	141	199	146	134	134	137	121
	148	48	43	64	46	74	52	43	40	42	35
	154	67	60	80	65	45	90	55	67	66	54
	160	156	97	155	144		160	72	78	97	129
	166		85	123	46		200	35	62	58	100
JUNE 21	172	141	105	148	77	99	70	61	79	92	115
	178	62	58	131	73		82	61	58	87	57
	184	149	143	197	125	213	149	115	110	158	128
	190	104	80	107	76	129	89	61	47	107	59
	196	100	91	103	84	105	92	73	68	81	63
	202	87		150	92	94	109	42	42	74	92
	208	57		92	79	50	81	55	46	82	52
	214	139		179	98	145	102	84	54	93	74
	220	52		83	49	93	27	41	31	45	42
	226			114	55	136		68	79	80	68
	232	65	82	88	66	80	80	64	61	67	60
	238	90	78	180	66	99	92	41	57	84	
	244	66	45	70	46	191	54	56	36	57	61
	250	149	95	143	99	149	139	101	78	129	105
	256		85	152	72	91	91	64	65		63
	262		92	215	83	111	122	70	73		92

TOTAL SUSPENDED PARTICULATE (ug/m^3)

DAY	JULIAN DAY	29000	29009	29011	29012	29017	29025	29067	29087	29089	29098
SEPT. 21	268		53	95	61	144	81	52	41	69	46
	274		69	133	77	124	108	77	51	68	89
	280	20	23	48	20	27	21	16	15	18	14
	286	131	59	136	66	177	81	56	50	73	54
	292	80	37	83	73	57		40	30	28	43
	298	116	111	216	114	185	139	99	83	147	89
	304	85	57	105	86	113	88	65	42	71	57
	310	64	29	72	35	54	45	28	26	42	30
	316	28	23	45	33		32	22	27	32	18
	322	37	28	46	44	45	43	39	36	38	26
	328	103	56	98	73	178	79	54	55	77	47
	334	51	42	90	56	94	47	49	51	75	44
	340	32	48	61	57	59	60	45	40	55	43
	346	67	70	102	61	67	77	50	60	64	59
	352	49	40	81	55	64	46	51	38	41	39
DEC. 21	358	56	39	52	46	50	61	45	41	47	32
	364	43	40	94	66	42	58	53	36	32	41

TABLE 11

TOTAL SUSPENDED PARTICULATE (ug/m^3)

DAY	JULIAN DAY	29102	29113	29114	29118	29119	29122	29124	29130	29135
JAN 4	4	70	44		25	44	36	64	29	33
	10	149	89	68	61	102	81	67	71	75
	16	139	54		33	68	46	67	33	32
	22	73	61	44	31	51	45	30	37	34
	28	98	63	46	42	70	33	34	28	31
	34	56	71	47	49	111	11	38	36	42
	40	184	124	120	144	148	162	129	90	91
	46	82	152	66	60	101	41	53	40	49
	52	58	98	51	41	91	36	33	27	48
	58	146	62	46	46	75	32	27	31	41
	64	63	97	45	55	154	29	36	32	40
	70	66	120	105	92	66	40	77	60	61
	76	52	149	46	53	76	30	40	35	31
MAR. 21	82		206	101	111	98	37	70	56	71
	88	51	147	54	55	58	31	38	24	46
	94	73	128	62	40	91	36	48	26	30
	100	127	60	7	23	81	28	33	18	23
	106	93	83	71	40	79	47	54	30	
	112		109	53	46	90	37	35	35	46
	118		194	63	56	95	34	57	34	43
	124	123	120	63	67	118	55	55	40	49
	130	40	219	89	65	71	38	69	33	44
	136	81	205	116	92	149	72	92	49	91
	142		148	141	120	138	125	110	82	120
	148		52	39	34	60	30	35	24	28
	154	86	79	57	30	80	43	47		41
	160	55		102	85	132	55	102		54
	166	35	202	134	60	43	30	114	32	43
JUNE 21	172		191	87	70	93	44	84	42	48
	178	160	101	57	49		50		30	43
	184	123	151	97	99	110	76	77	59	90
	190	112	123	59	48	119	58		34	42
	196	72	121	66	52	90	68		41	54
	202	30	141	52	90	58	45	53	31	32
	208	118	85	53	45	106	58	43	28	41
	214	220	142	94	68	200	77	67	46	61
	220	116	67	37	31	86	44	32	23	22
	226	144	118	69	62	131	64	51	47	60
	232	89	114	59	50	100	65	49	39	44
	238	54	111	70	46	84	52	44	28	32
	244	92	71	39	38	87	47	107	28	28
	250	76	158	91	84	114	90	148	57	67
	256	44	161	78	52	119	187	138	27	45
	262	33	173	82	59	94	51	154	36	56

TOTAL SUSPENDED PARTICULATE (ug/m^3)

DAY	JULIAN DAY	29102	29113	29114	29118	29119	29122	29124	29130	29135
SEPT. 21	268	103	119	42	40	101	46	120	23	32
	274	66	110	65	67	94	64	132	42	47
	280	85	36	7		47	18	14	9	10
	286	144	108	46	53	131	53	50	25	43
	292	15	153		32	38	24	36	20	15
	298	128	182	95	65	129	84	74	44	59
	304	105	85	41	65	103	61	38	36	66
	310	81	62	26	29	90	28	26	17	23
	316	46	40		21	46	21	29	13	18
	322	102	49	23	32	44	34	29	22	26
	328	152	98	40	44	130	45	47	19	46
	334	74	81	41	47	89	42	41	25	37
	340	86	63	32		70	69	34	28	33
	346	47	110	40	55	86	69		41	54
	352	127	61			54	49		39	34
DEC. 21	358	115	50	30	43	54	46	31	41	31
	364	58	53	27	42	35	42	31	37	26