6.0 OZONE TRENDS AND WEEKDAY/WEEKEND EFFECTS

6.1 Introduction

As discussed in more detail elsewhere in this report (*i.e.*, section 4.0), an initial examination of the ozone air quality data for the 1986 through 1993 smog seasons revealed a substantial downward trend both in the number of first stage ozone alerts and in a variety of other air quality metrics for ozone for all three areas of the SoCAB: western, mid-basin and eastern. This preliminary examination also showed a distinct trend towards more of the highest daily ozone values occurring on weekend days rather than on weekdays.

This observation agreed with findings for earlier years (*i.e.*, the late 1970's through the mid-1980's) reported by several researchers (*e.g.*, Horie 1988; Hoggan *et al.* 1989). In particular, Horie (1988) examined the weekday/weekend differences for portions of the two three-year time periods 1975-77 and 1984-86 which had apparently similar meteorological conditions, while Hoggan *et al.* (1989) examined the weekday/weekend differences in the six criteria pollutants for three different 3-year time periods (1978-80, 1982-84, and 1985-87). A number of other earlier investigations of weekday/weekend effects have been reported as well (Cleveland *et al.* 1974; Lebron 1975; Levitt and Chock 1975; Elkus and Wilson 1977; Graedel *et al.* 1977; Zeldin *et al.* 1989; Hoggan *et al.* 1989). However, to our knowledge, no detailed analysis of weekend/weekday ozone differences in the SoCAB for the eight-year period 1986-1993 has been reported prior to our present study. In this section of the report, we describe various analyses of weekday/weekend differences in SoCAB air quality.

6.2 Seasonal Mean Daily Maximum Ozone By Day of the Week

The ozone database (1986-93) was analyzed for differences in daily ozone maxima on weekdays vs. weekend days for the air pollution season (May-October). Data for selected stations in three different geographical areas [*i.e.*, western (or coastal), mid-basin, and eastern] were analyzed to identify weekday/weekend differences as a function of location in the Basin. The West LA and Central LA stations were used for the western area, Pasadena and Azusa for the mid-basin area, and Redlands and Riverside for the eastern area.

The ozone database contains hourly observations for each day for all stations. This database was analyzed to determine the daily maximum ozone concentration for each day of the week, and the mean daily maximum ozone concentration for the entire air pollution season (May-October) for each day of the week. The standard deviations for each day of the week were also computed to examine the degree of variation in the daily ozone peaks.

As an example, daily maximum ozone values for Azusa for (1 May - 31 October) 1986 are shown in Table 6-1. Although there is a clear trend toward higher mean daily maximum ozone values as the week progresses, with the highest values found for weekend days, the difference in the means is much smaller than the sum of the standard deviations. The standard deviations for all days of the week are substantial, reflecting the high degree of variation in daily maximum ozone values at Azusa even during the smog season. Similar results were obtained from analyses of ozone data for the West LA and Pasadena stations.

These results suggest that simple averages of daily ozone maxima are not a useful metric for distinguishing weekday/weekend differences. We were then led to examine other metrics, including an "exposure"-type metric (*e.g.*, cumulative pphm-hours above the Federal ozone standard).

6.3 Daily Maximum Ozone Distributions for Weekdays vs. Weekend Days

For the 1986-93 period, daily maximum ozone data for stations at Central LA, Azusa and Riverside were examined for weekday/weekend differences in the distribution of ozone concentrations (Figure 6-1 through Figure 6-24). In this analysis, Monday and Tuesday were used as a representative pair of weekdays to compare with Saturday/Sunday data. The Monday/Tuesday and Saturday/Sunday distributions of daily maximum ozone concentration levels for Azusa for the 1986 through 1993 air pollution seasons are shown in Figures 6-9 to 6-16. From these figures, it can be seen that many of the higher daily maximum ozone concentrations occurred on weekend days while the lower daily

Table 6-1. Daily (hourly-average) Maximum Ozone Concentration (May 1 - Oct. 31) for Azusa in 1986 (pphm).

NWK	MON	TUE	WED	THU	FRI	SAT	SUN
1	a	a	a	18	14	7	7
2	6	5	5	9	17	9	7
3	9	11	7	7	14	19	23
4	15	10	9	11	12	22	24
5	14	18	20	13	8	11	9
6	11	19	15	11	11	15	14
7	16	18	17	18	18	20	15
8	12	15	16	16	16	17	22
9	21	21	21	31	28	19	13
10	15	14	19	9	7	8	9
11	13	14	13	13	14	16	16
12	15	5	10	12	18	22	24
13	9	10	15	13	12	16	15
14	15	24	21	22	21	21	21
15	19	15	17	23	23	23	23
16	22	20	16	20	19	21	23
17	21	21	21	19	24	19	20
18	14	22	18	21	22	15	11
19	12	15	19	25	25	31	25
20	15	6	10	16	10	9	12
21	12	14	14	6	7	9	13
22	9	5	2	4	5	6	8
23	14	13	3	4	10	9	7
24	15	13	11	7	5	4	10
25	7	10	10	13	9	9	12
26	9	6	8	10	11	13	23
27	17	13	23	13	9	a	a
AVE	13.7	13.7	13.8	14.2	14.4	15	15.6
STDEV	4.2	5.6	5.9	6.7	6.4	6.6	6.3

[a] These days fall outside the May 1 - October 31 period.

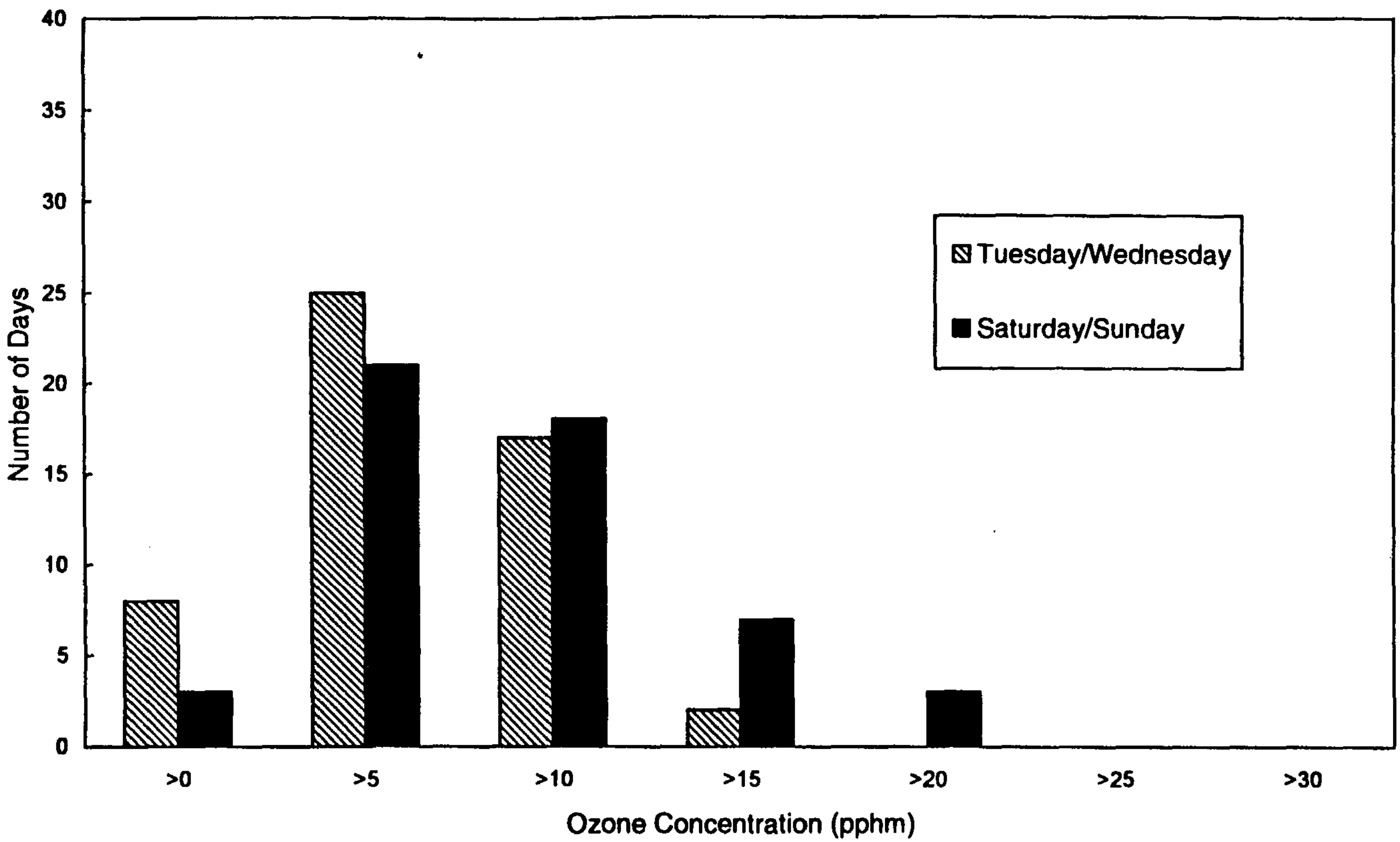

Figure 6-1. Distribution of daily ozone maxima (May 1 - October 31, 1986) for Central Los Angeles.

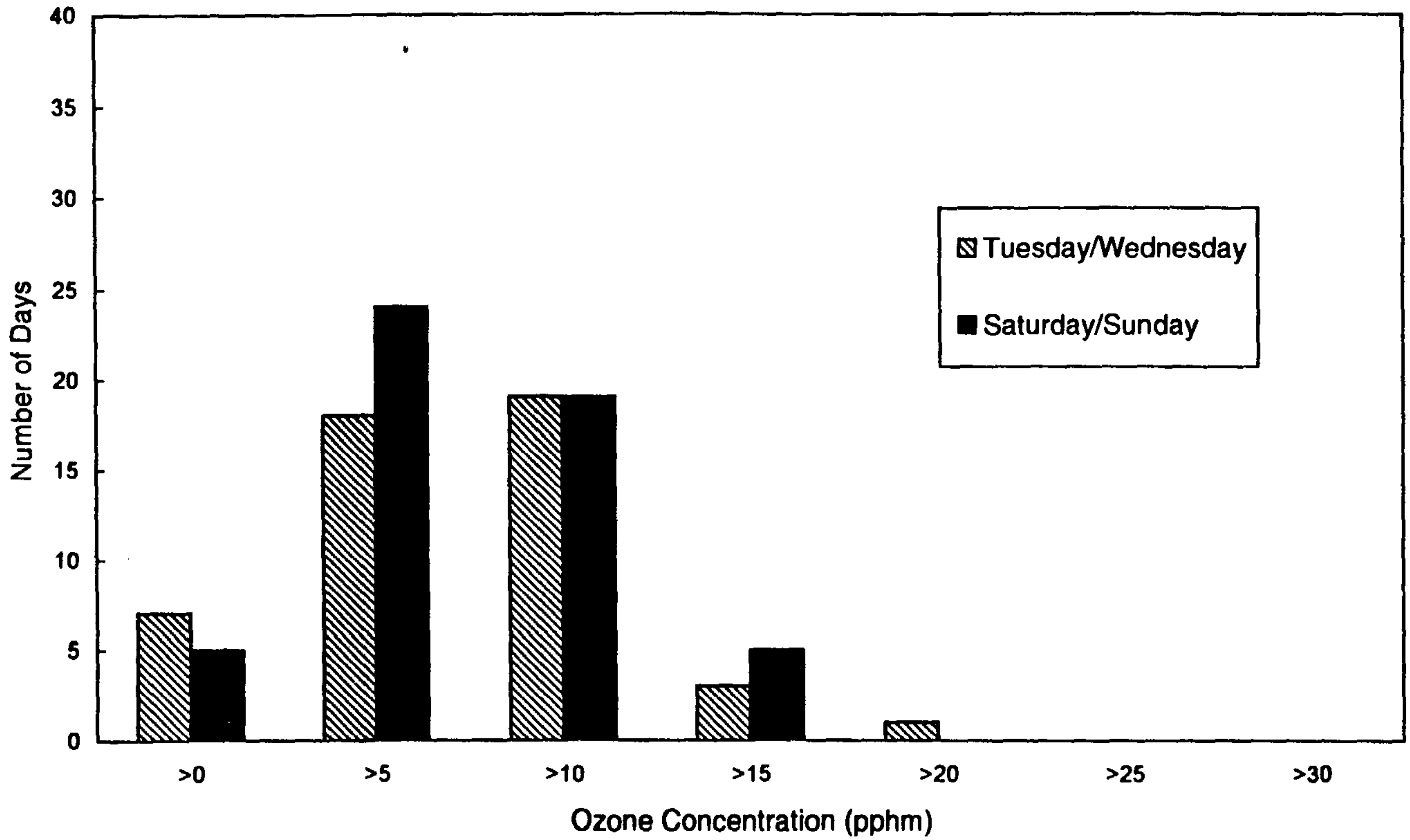

Figure 6-2. Distribution of daily ozone maxima (May 1 - October 31, 1987) for Central Los Angeles.

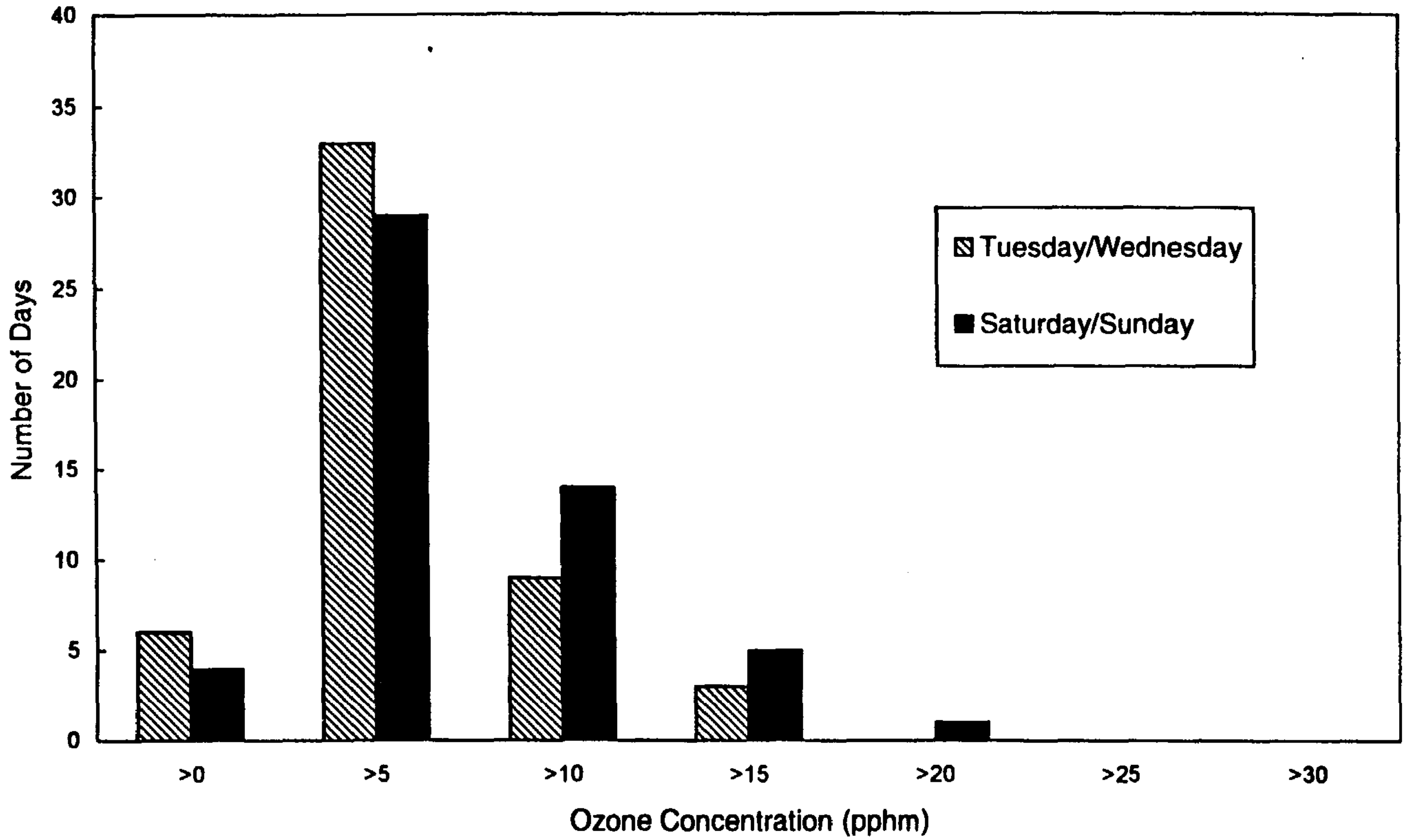

Figure 6-3. Distribution of daily ozone maxima (May 1 - October 31, 1988) for Central Los Angeles.

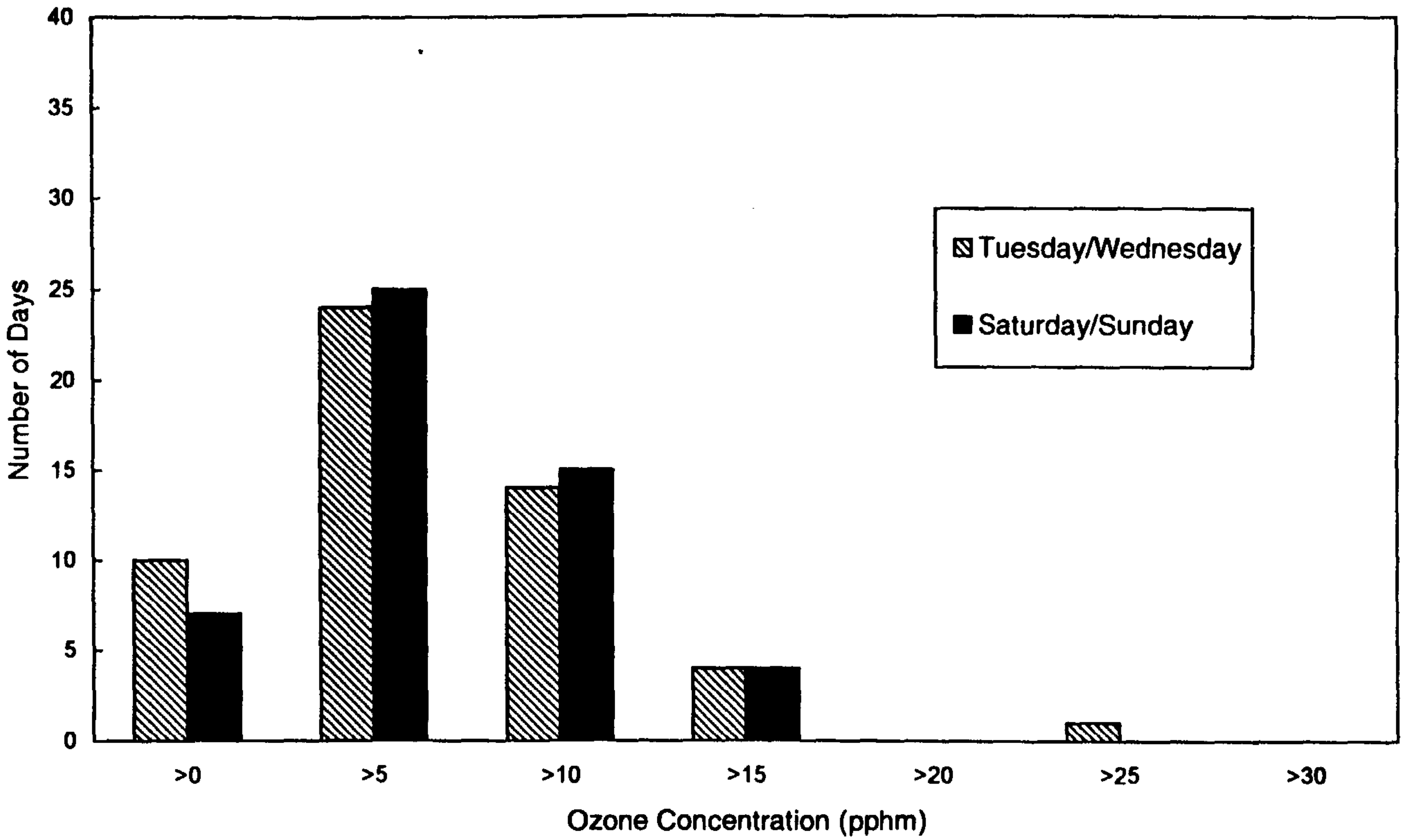

Figure 6-4. Distribution of daily ozone maxima (May 1 - October 31, 1989) for Los Angeles.

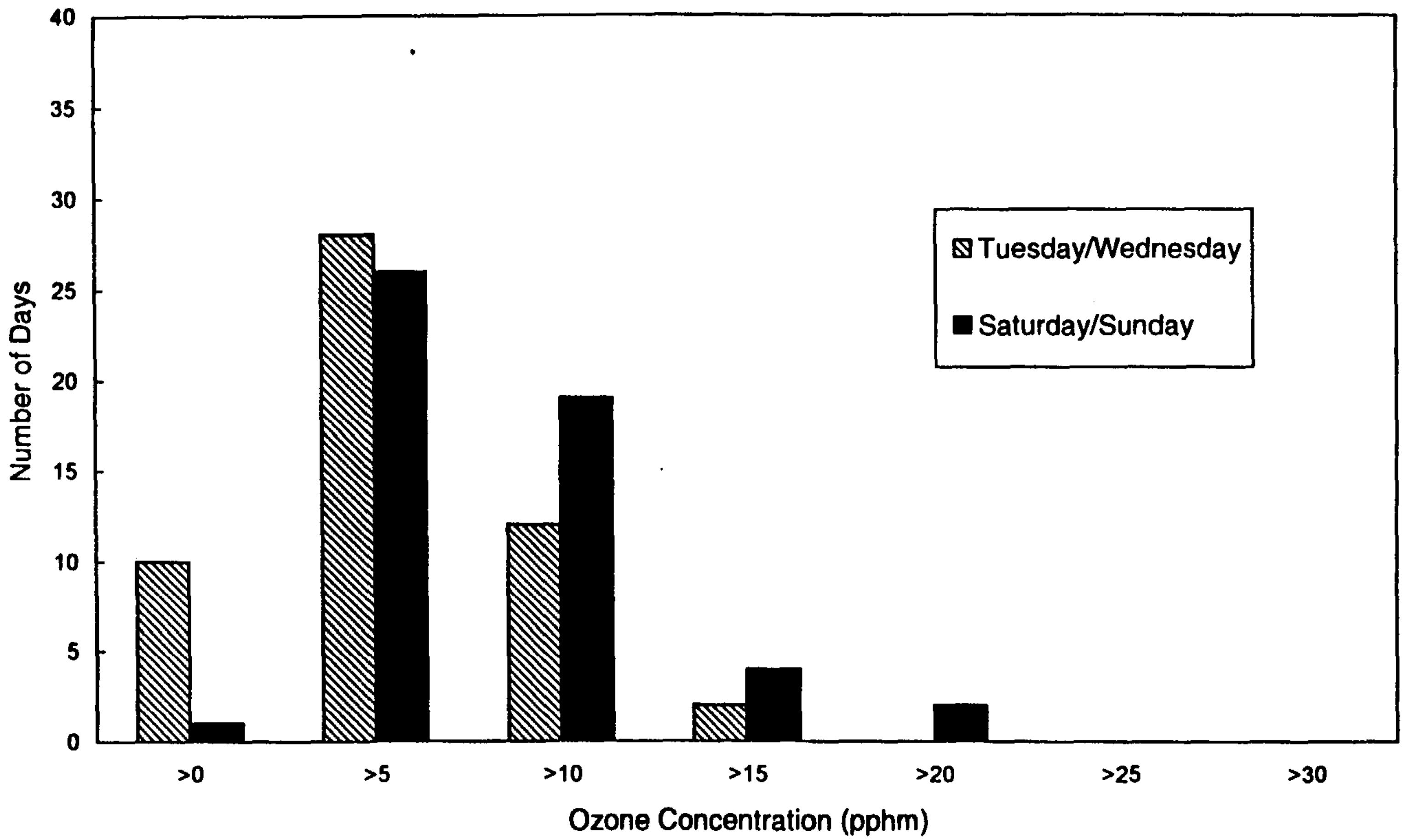

Figure 6-5. Distribution of daily ozone maxima (May 1 - October 31, 1990) for Central Los Angeles.

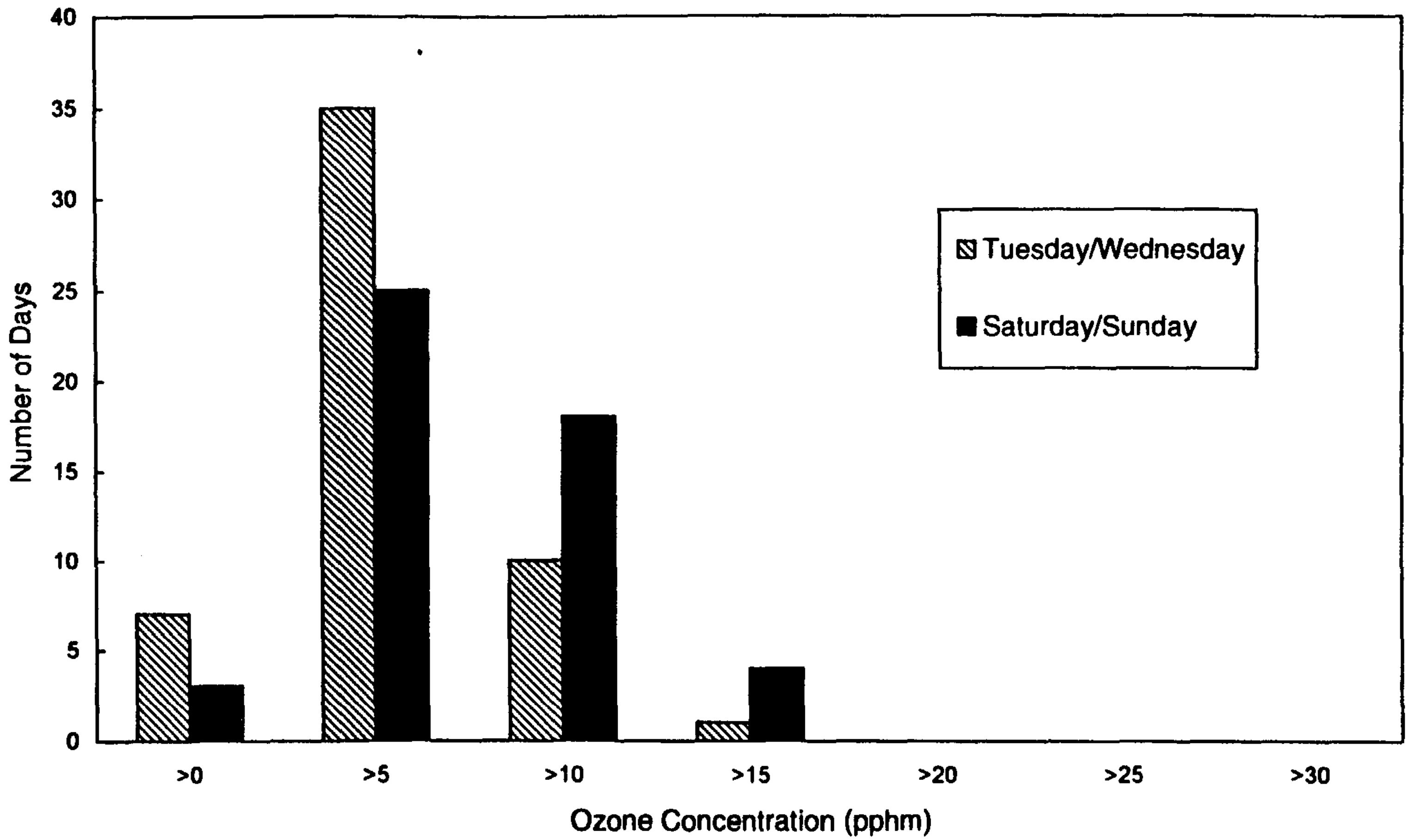

Figure 6-6. Distribution of daily ozone maxima (May 1 - October 31, 1991) for Central Los Angeles.

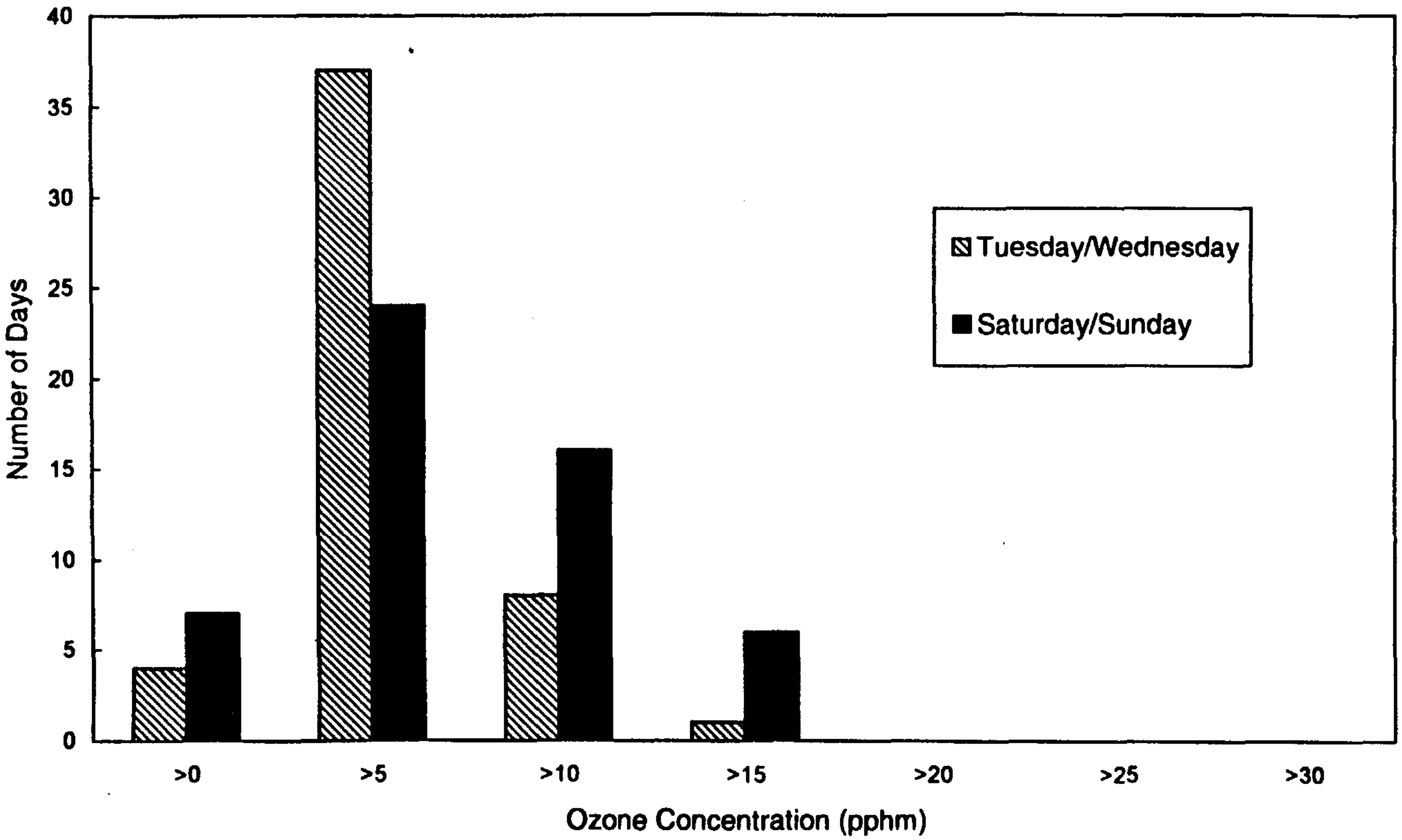

Figure 6-7. Distribution of daily ozone maxima (May 1 - October 31, 1992) for Los Angeles.

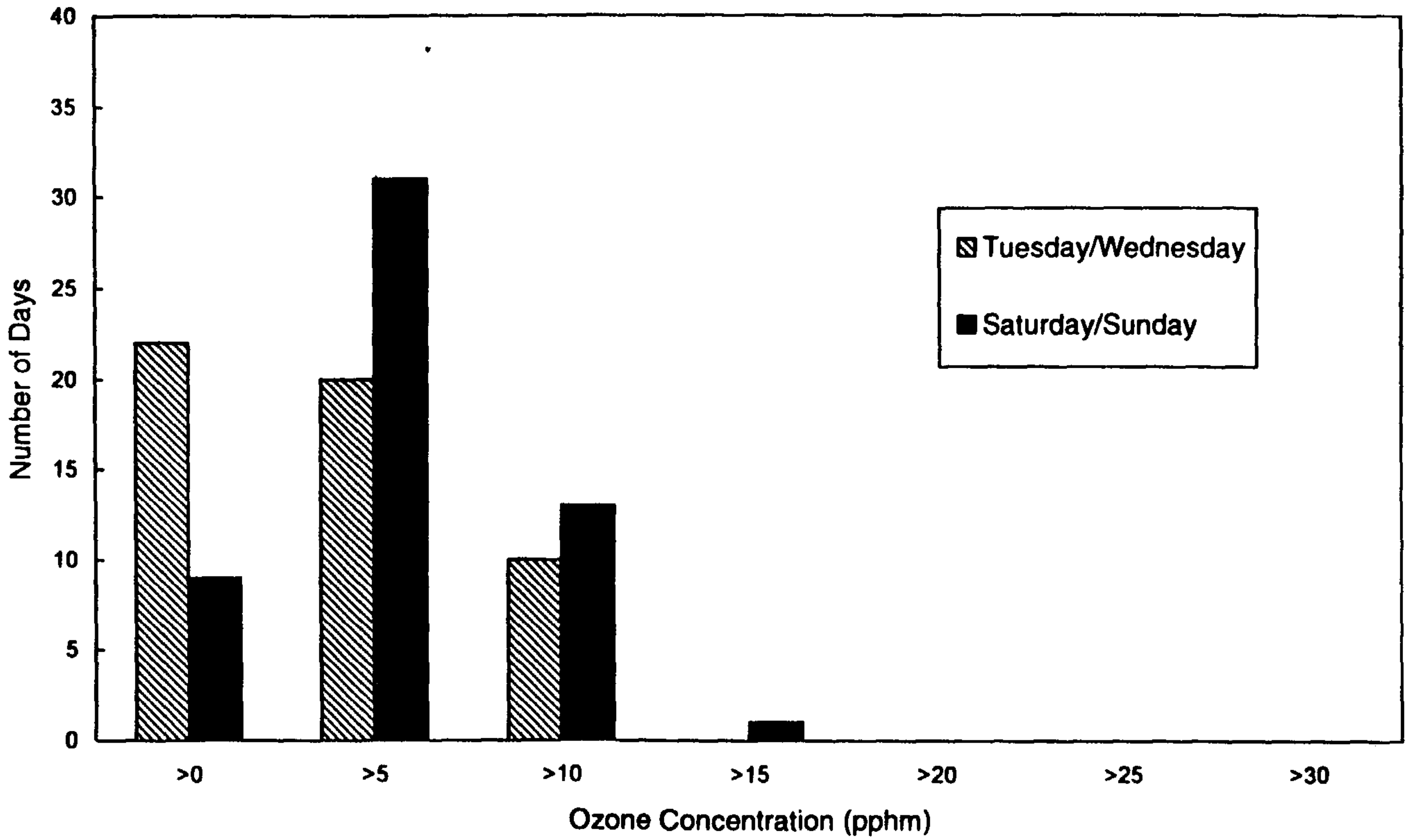

Figure 6-8. Distribution of daily ozone maxima (May 1 - October 31, 1993) for Central Los Angeles.

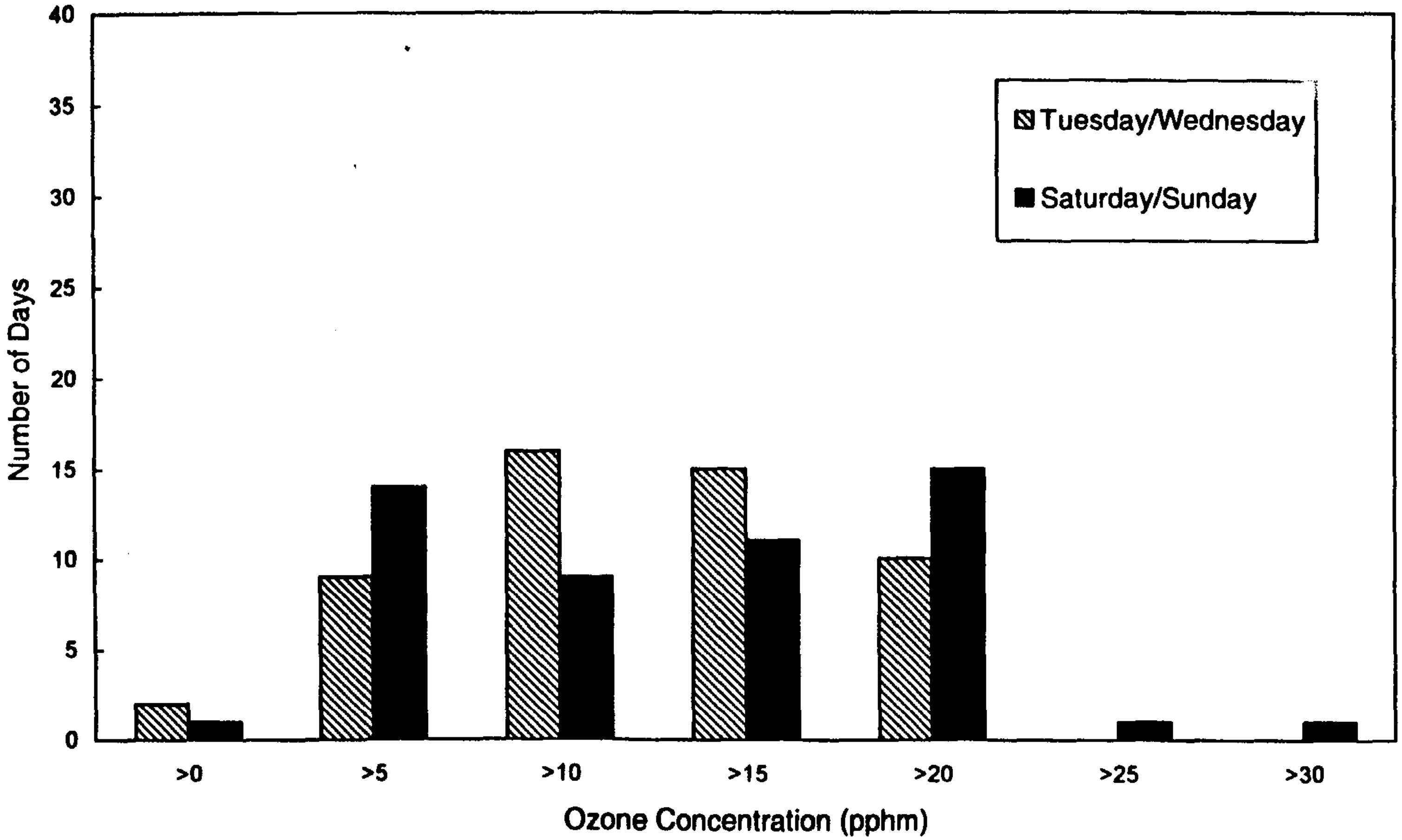

Figure 6-9. Distribution of daily ozone maxima (May 1 - October 31, 1986) for Azusa.

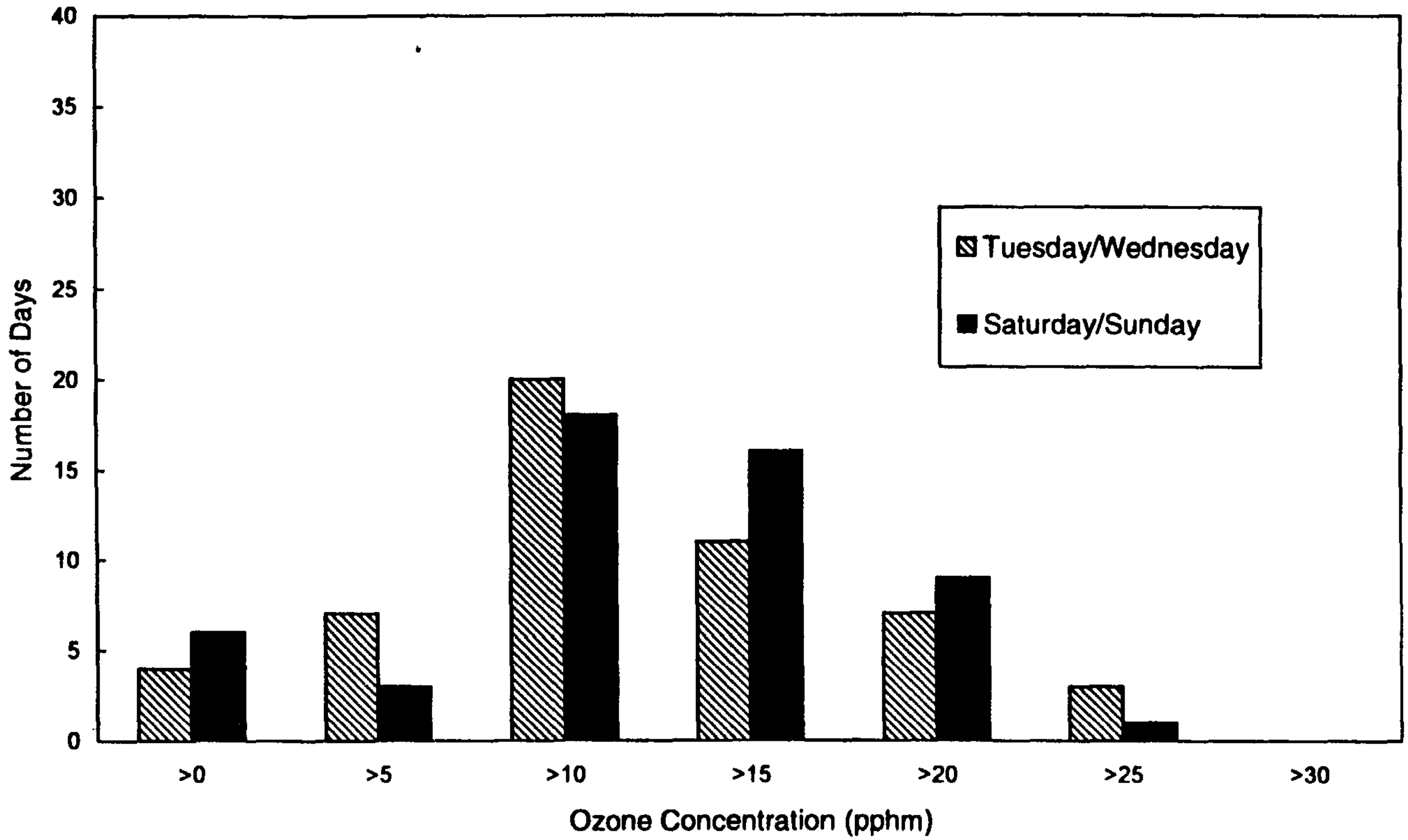

Figure 6-10. Distribution of daily ozone maxima (May 1 - October 31, 1987) for Azusa.

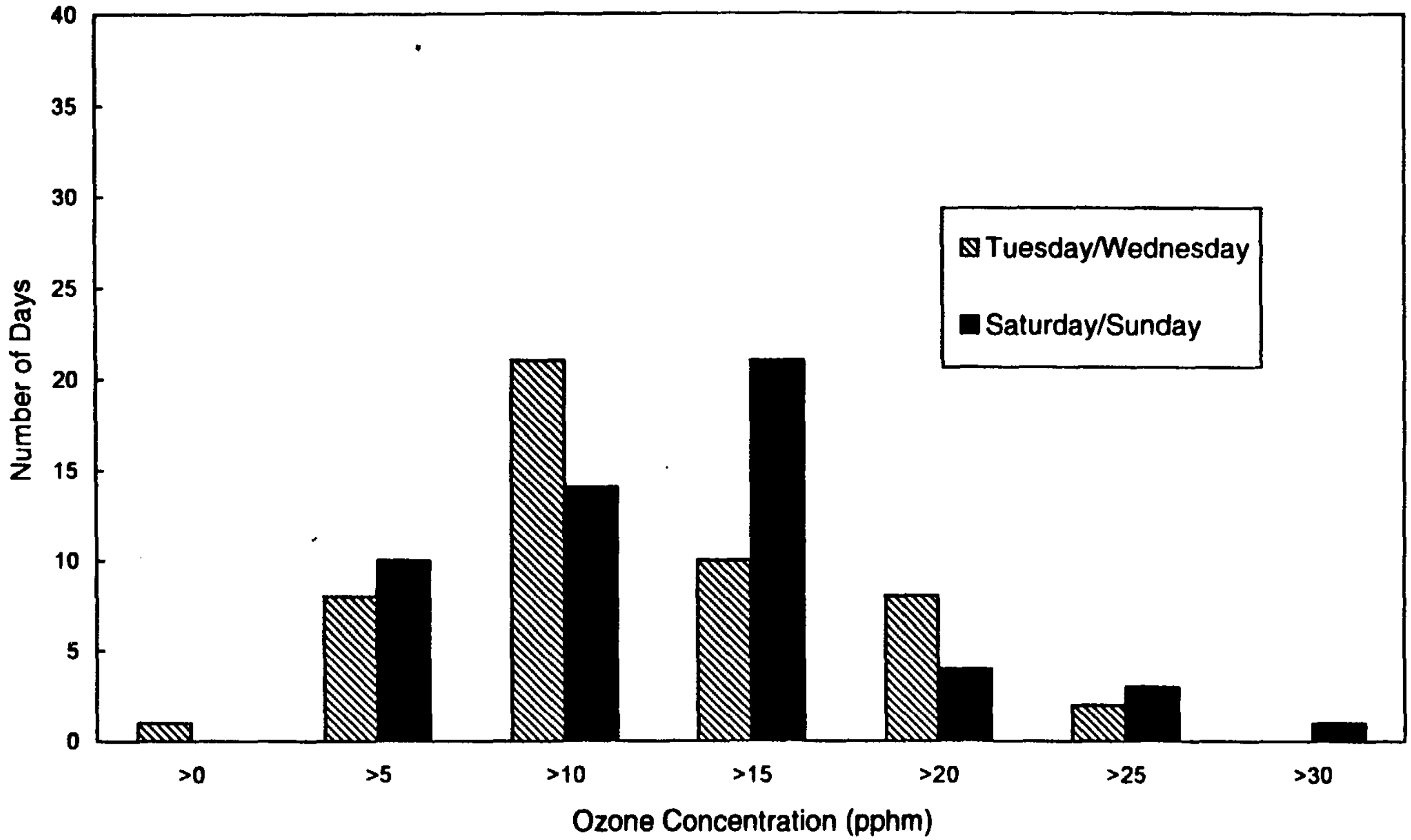

Figure 6-11. Distribution of daily ozone maxima (May 1 - October 31, 1988) for Azusa.

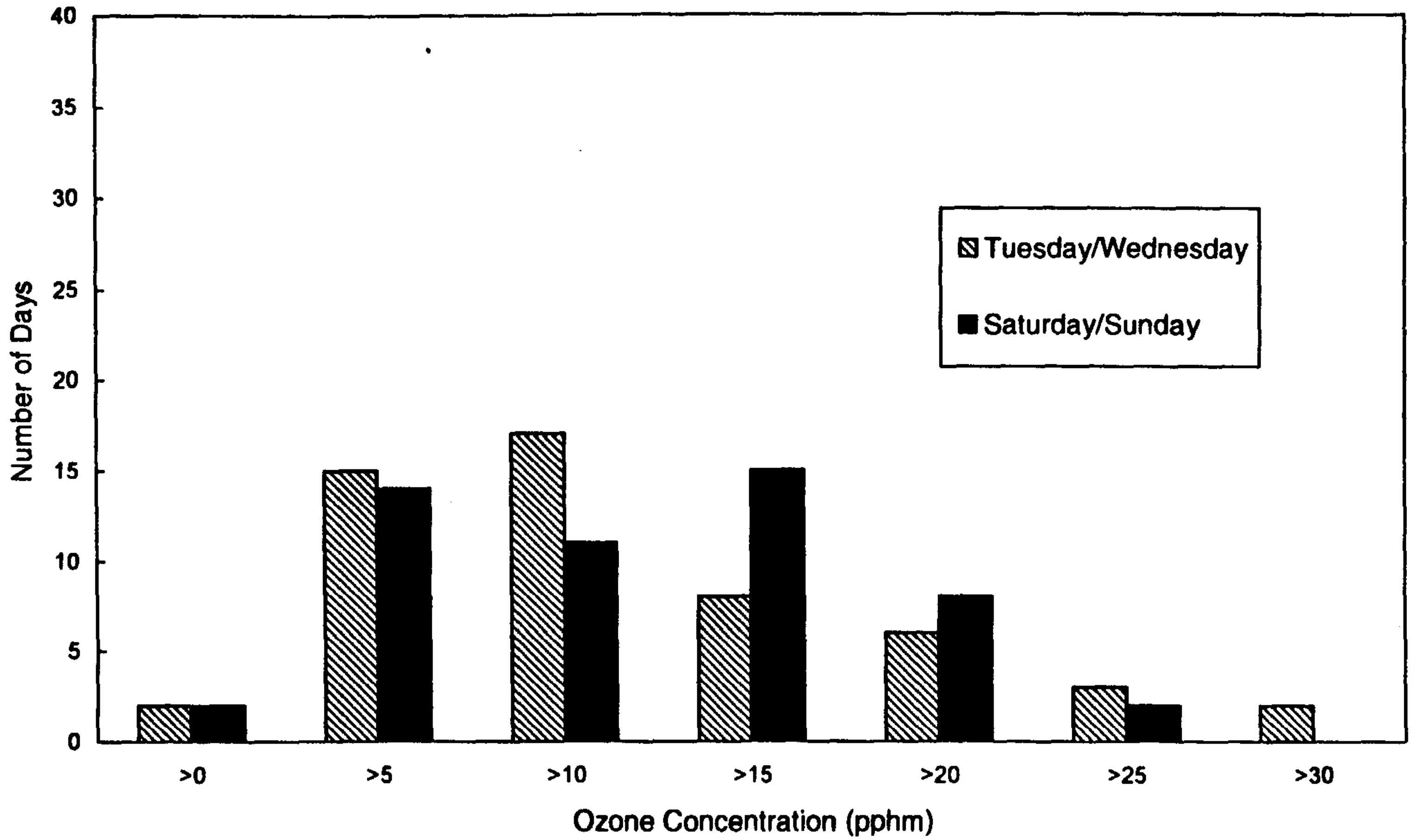

Figure 6-12. Distribution of daily ozone maxima (May 1 - October 31, 1989) for Azusa.

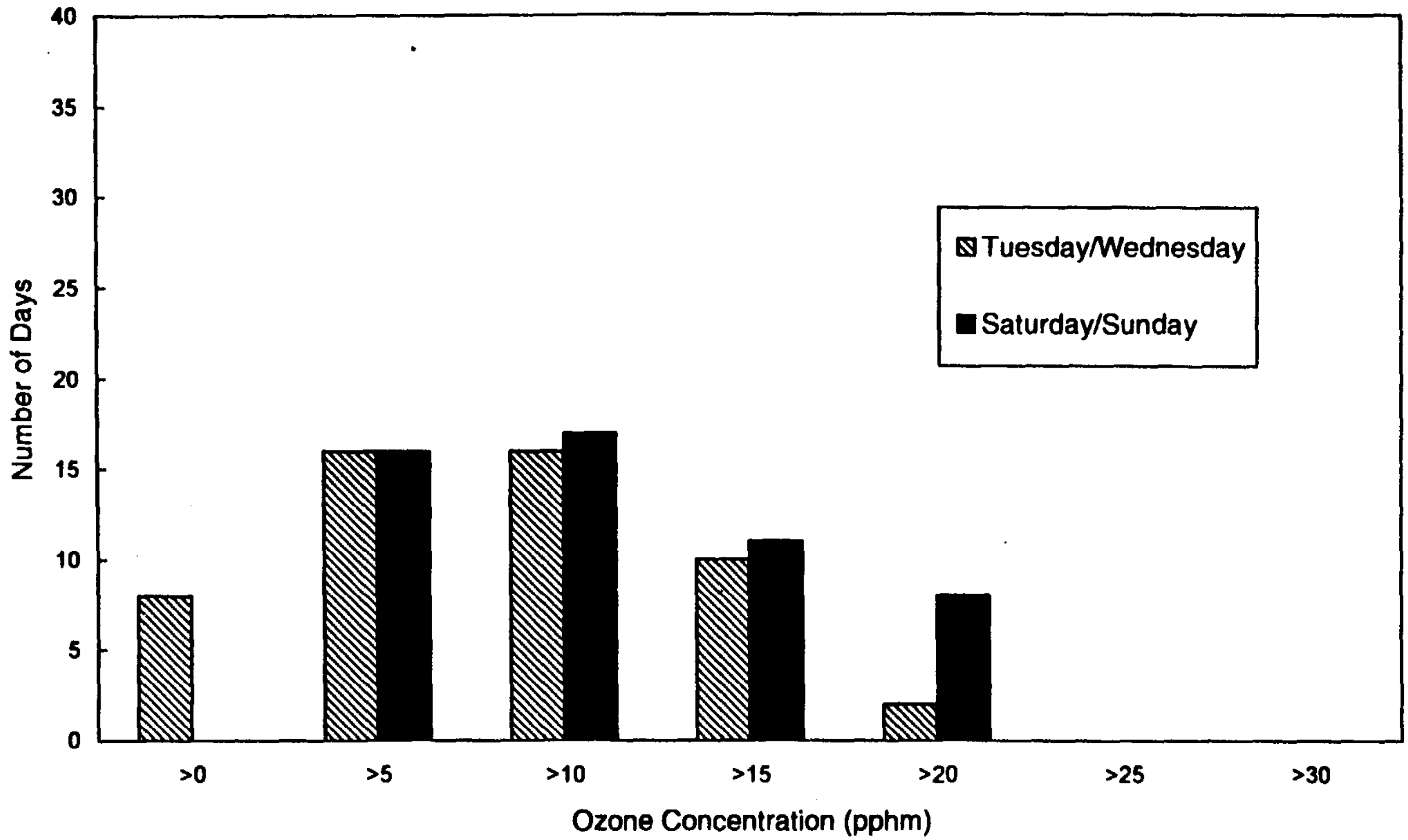

Figure 6-13. Distribution of daily ozone maxima (May 1 - October 31, 1990) for Azusa.

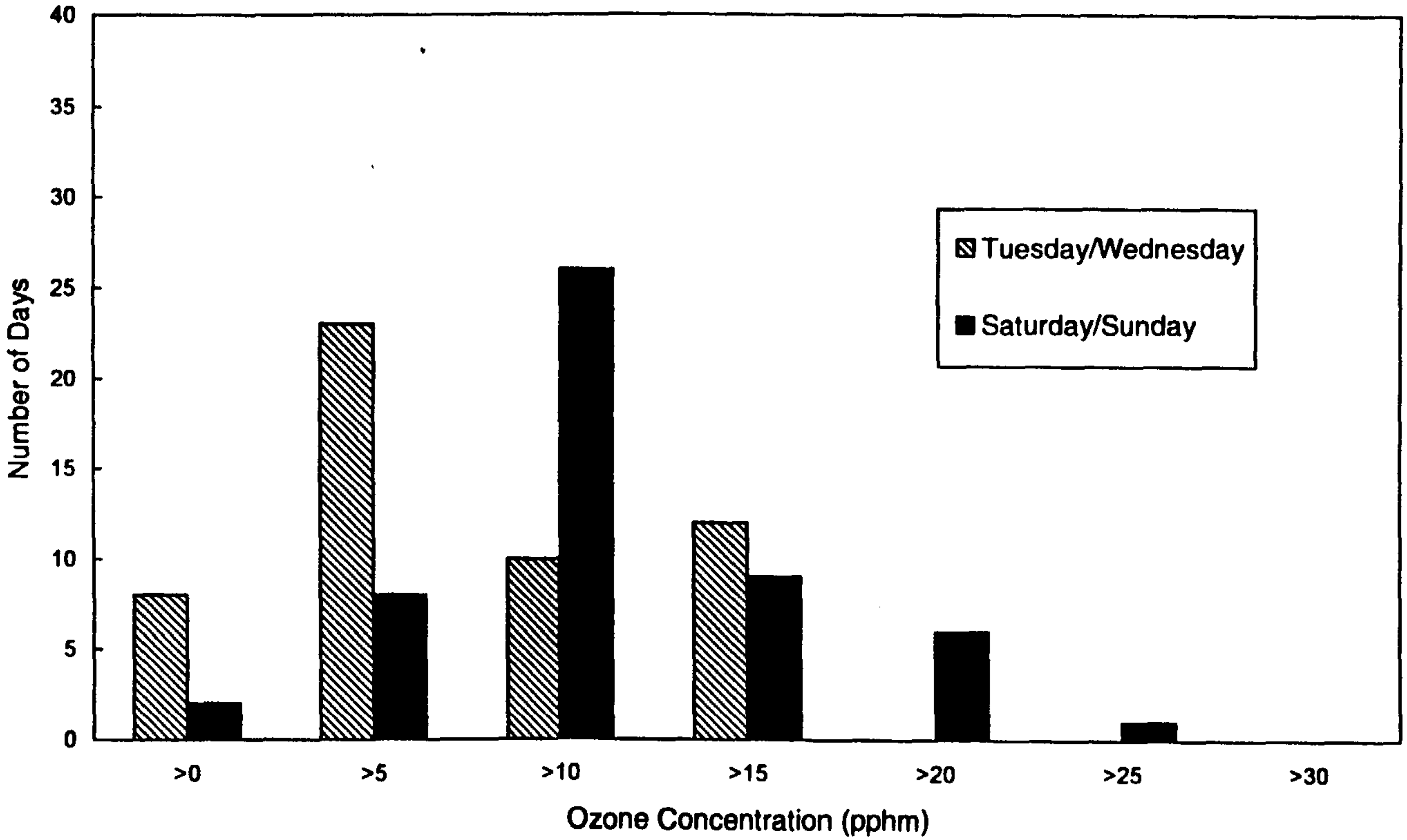

Figure 6-14. Distribution of daily ozone maxima (May 1 - October 31, 1991) for Azusa.

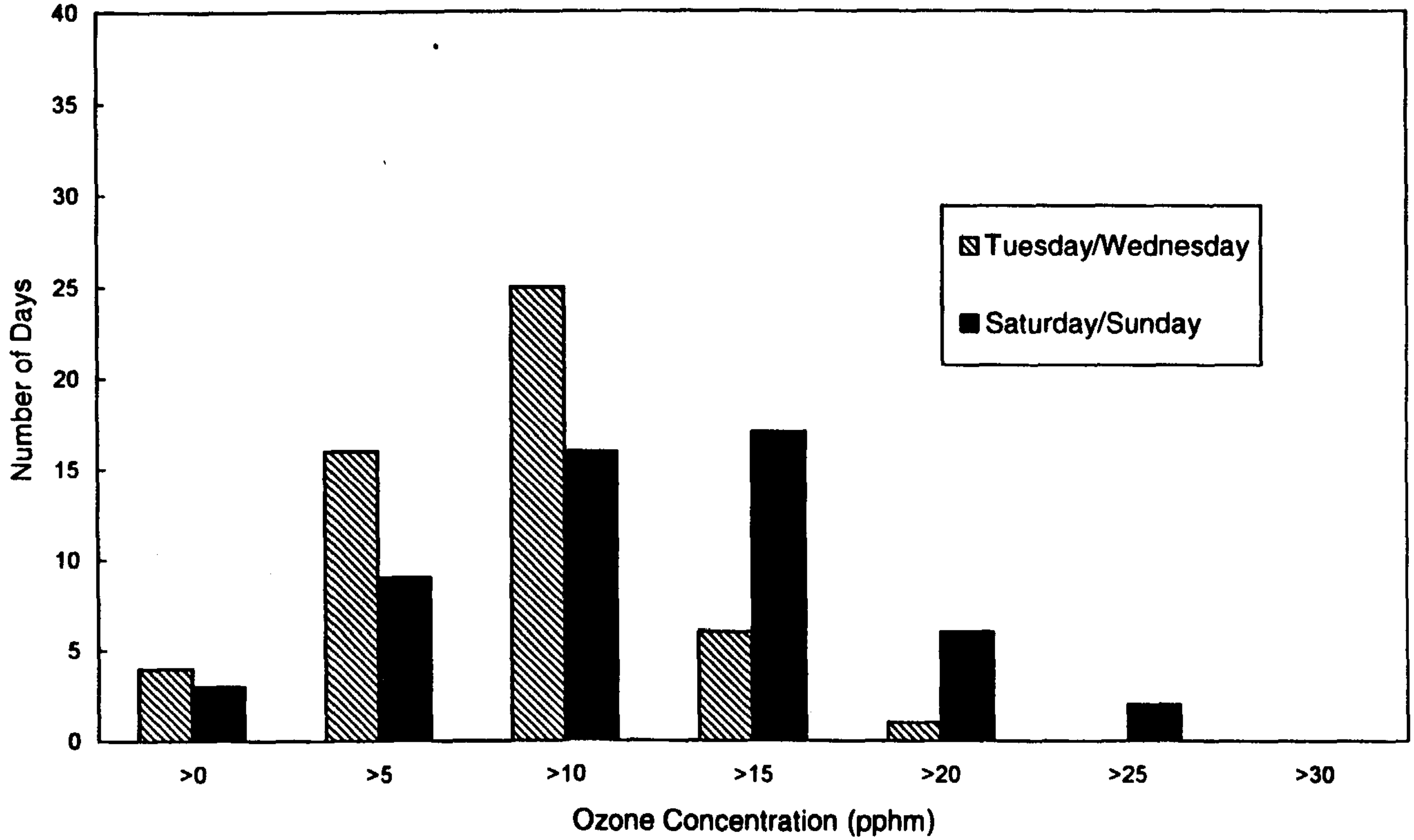

Figure 6-15. Distribution of daily ozone maxima (May 1 - October 31, 1992) for Azusa.

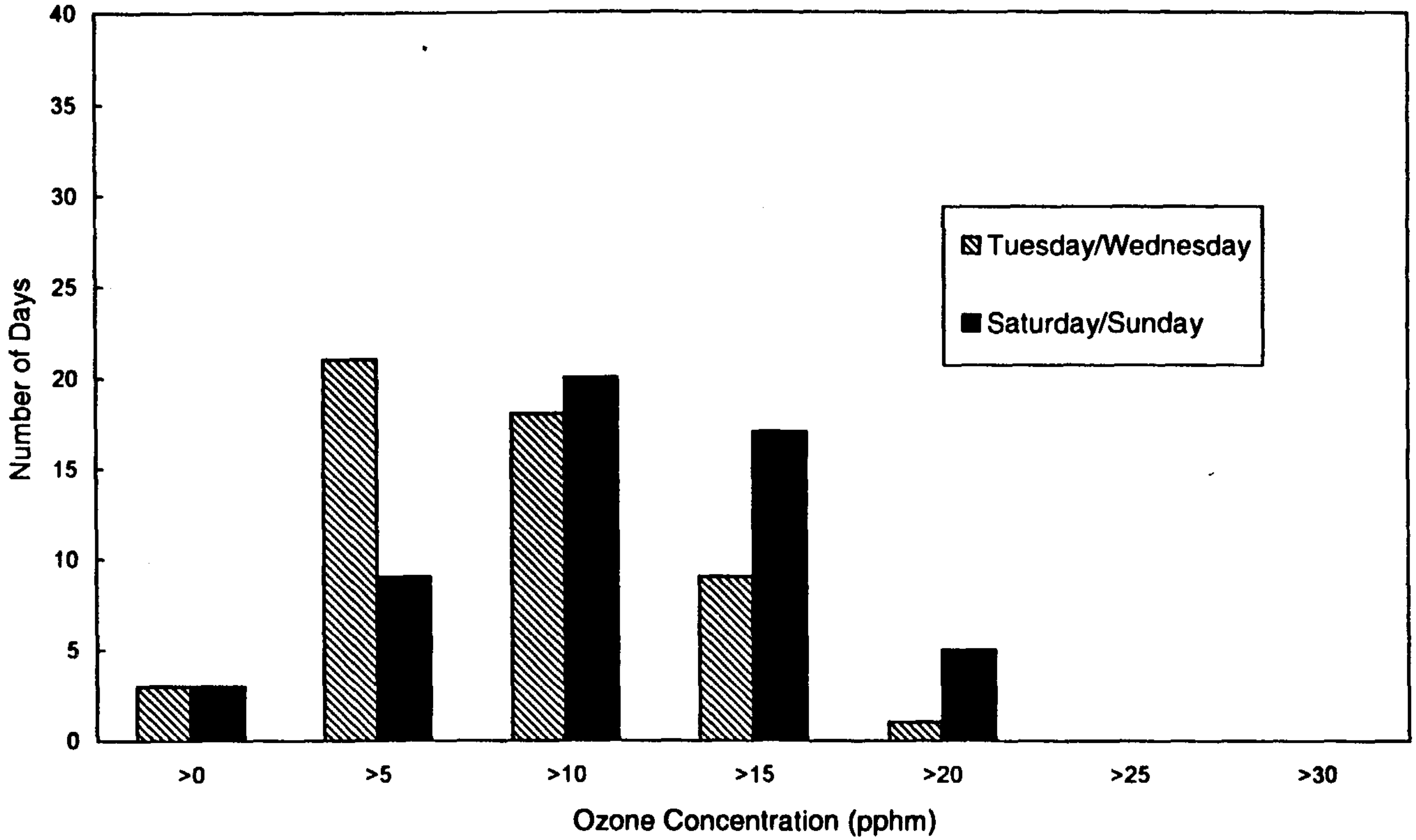

Figure 6-16. Distribution of daily ozone maxima (May 1 - October 31, 1993) for Azusa.

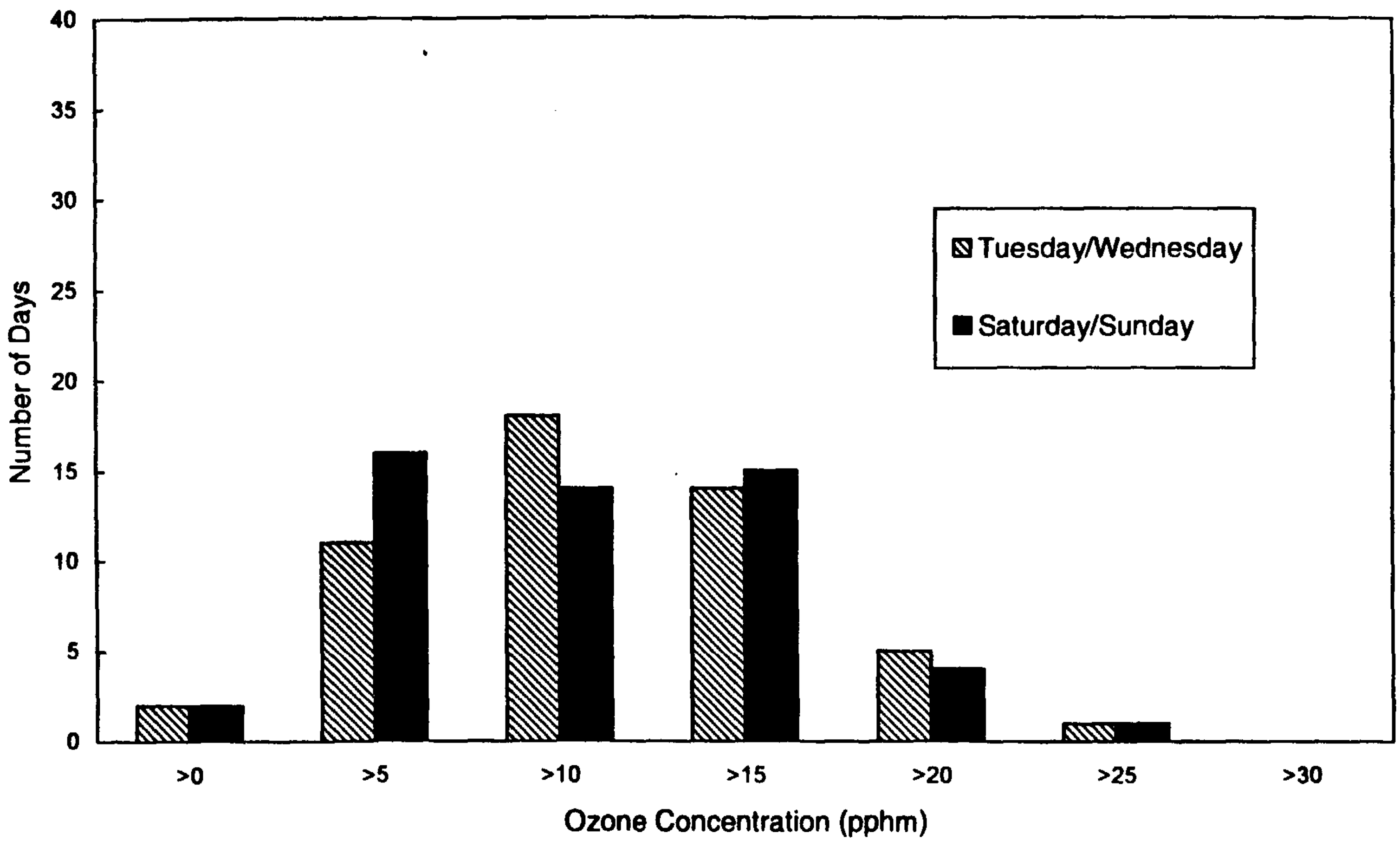

Figure 6-17. Distribution of daily ozone maxima (May 1 - October 31, 1986) for Riverside.

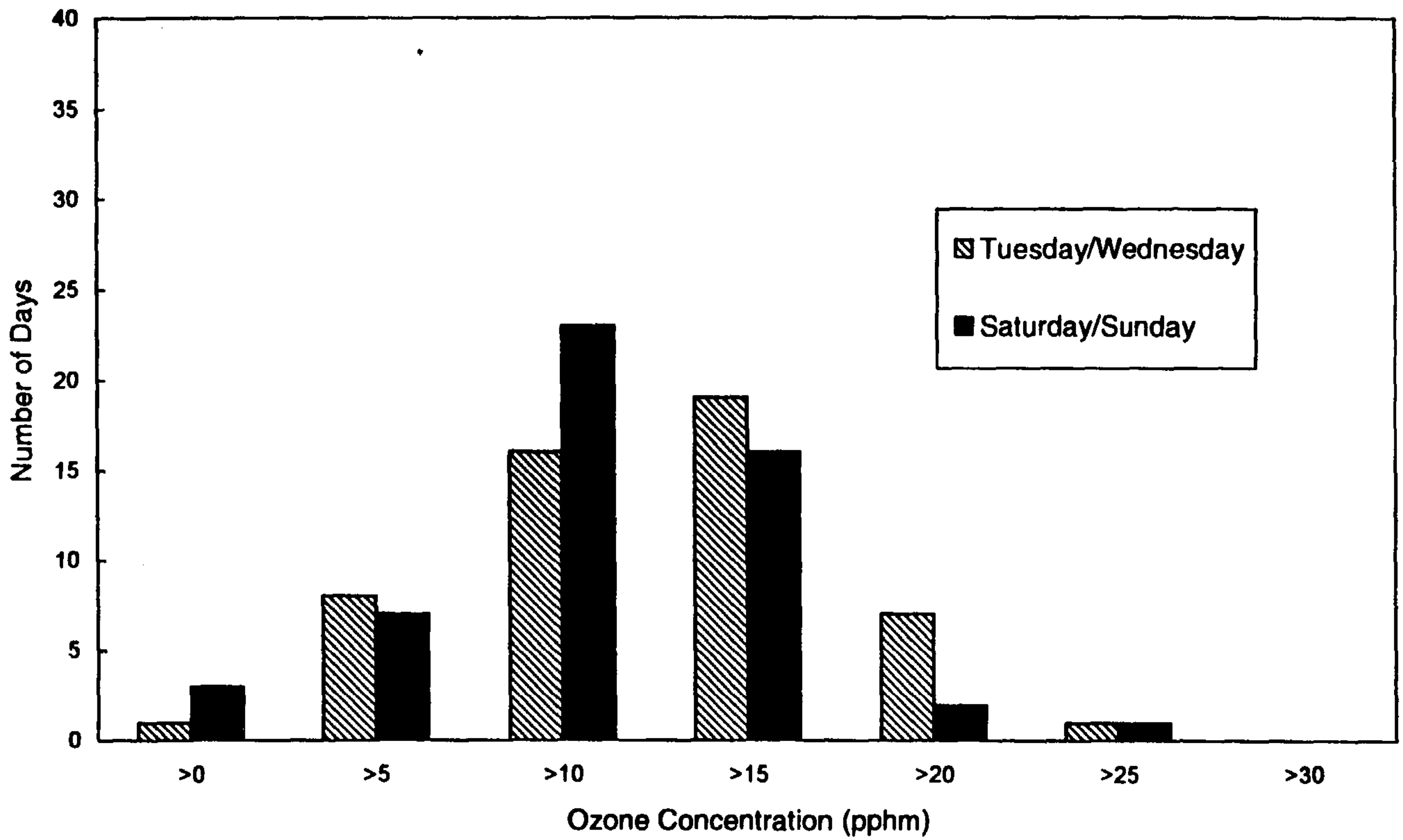

Figure 6-18. Distribution of daily ozone maxima (May 1 - October 31, 1987) for Riverside.

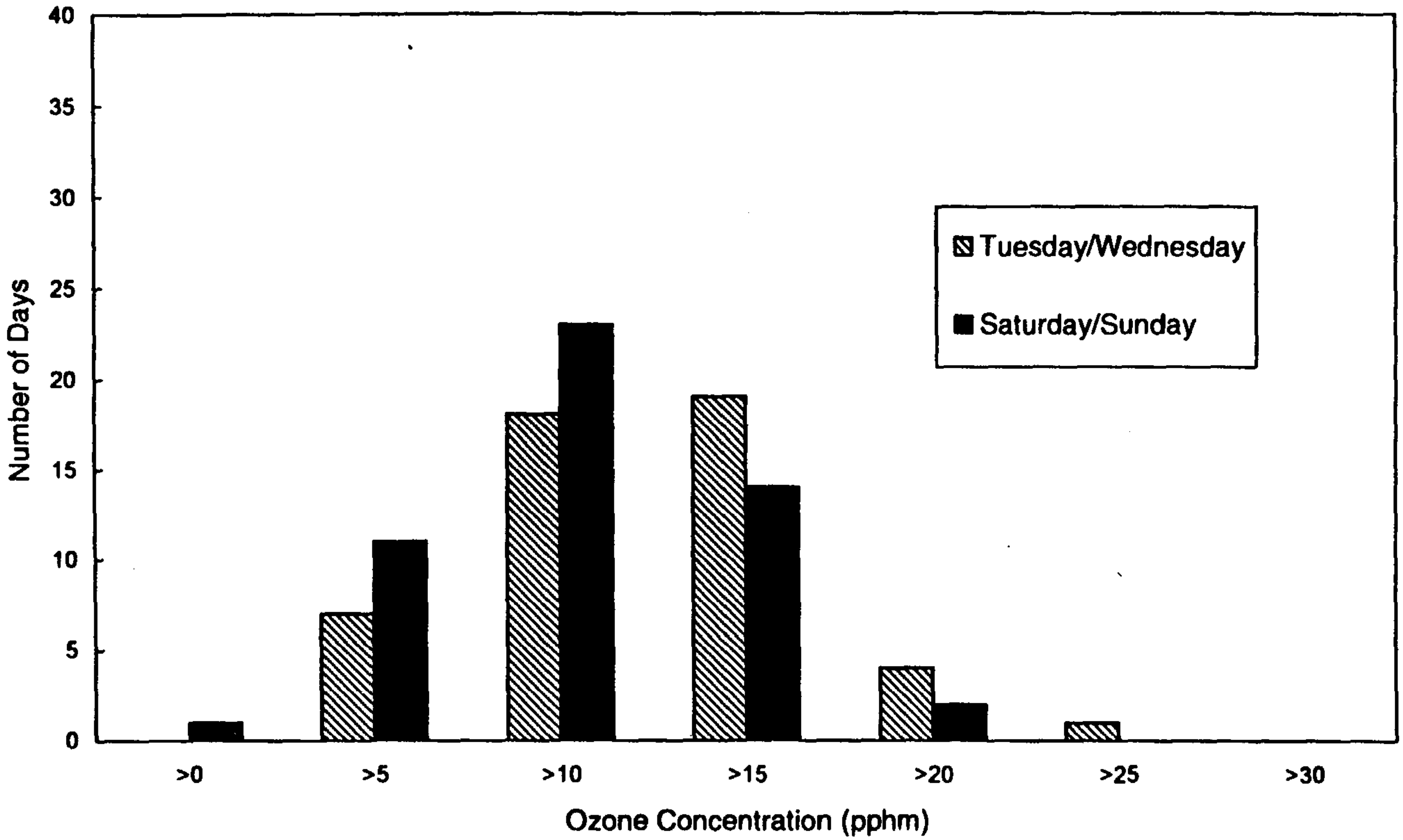

Figure 6-19. Distribution of daily ozone maxima (May 1 - October 31, 1988) for Riverside.

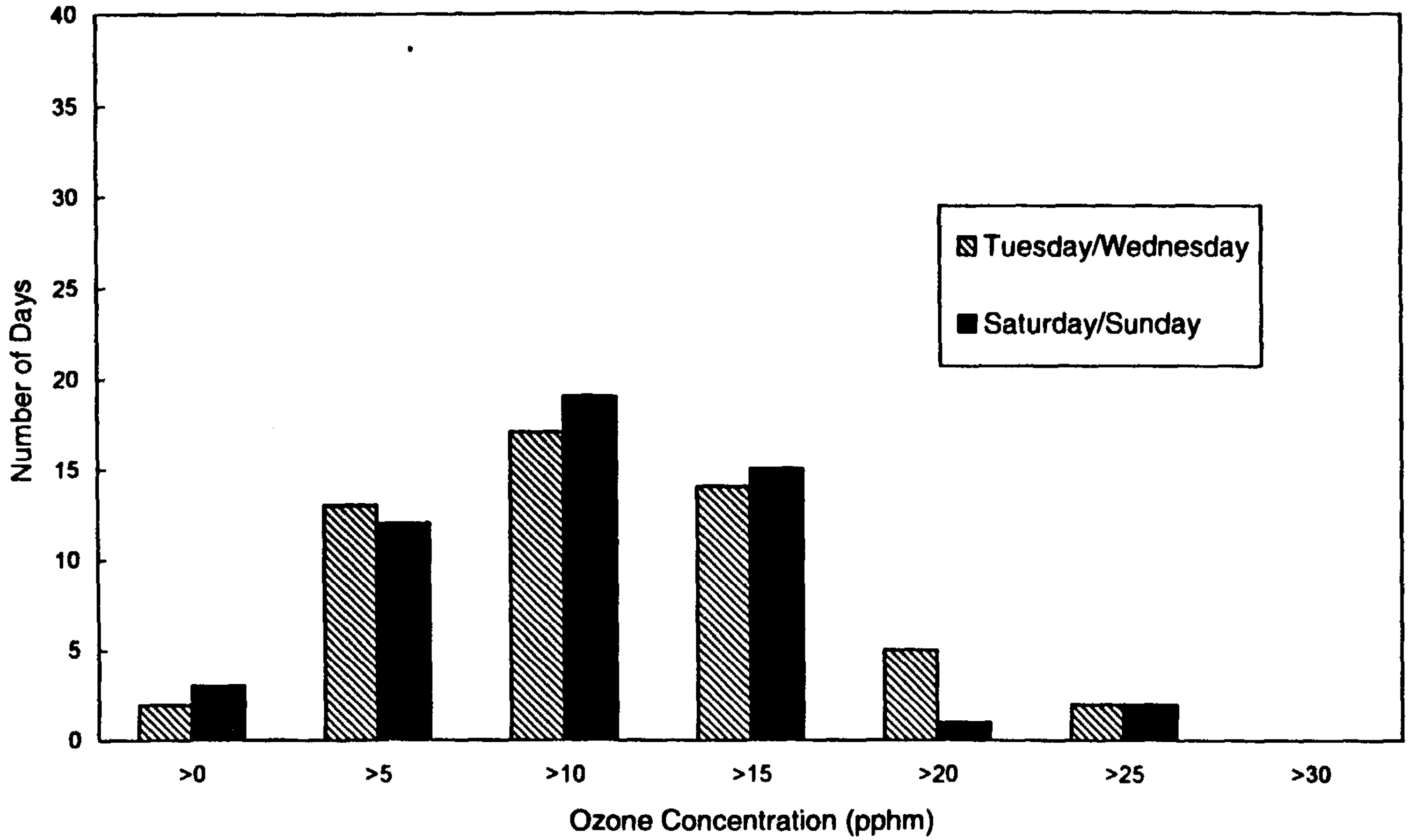

Figure 6-20. Distribution of daily ozone maxima (May 1 - October 31, 1989) for Riverside.

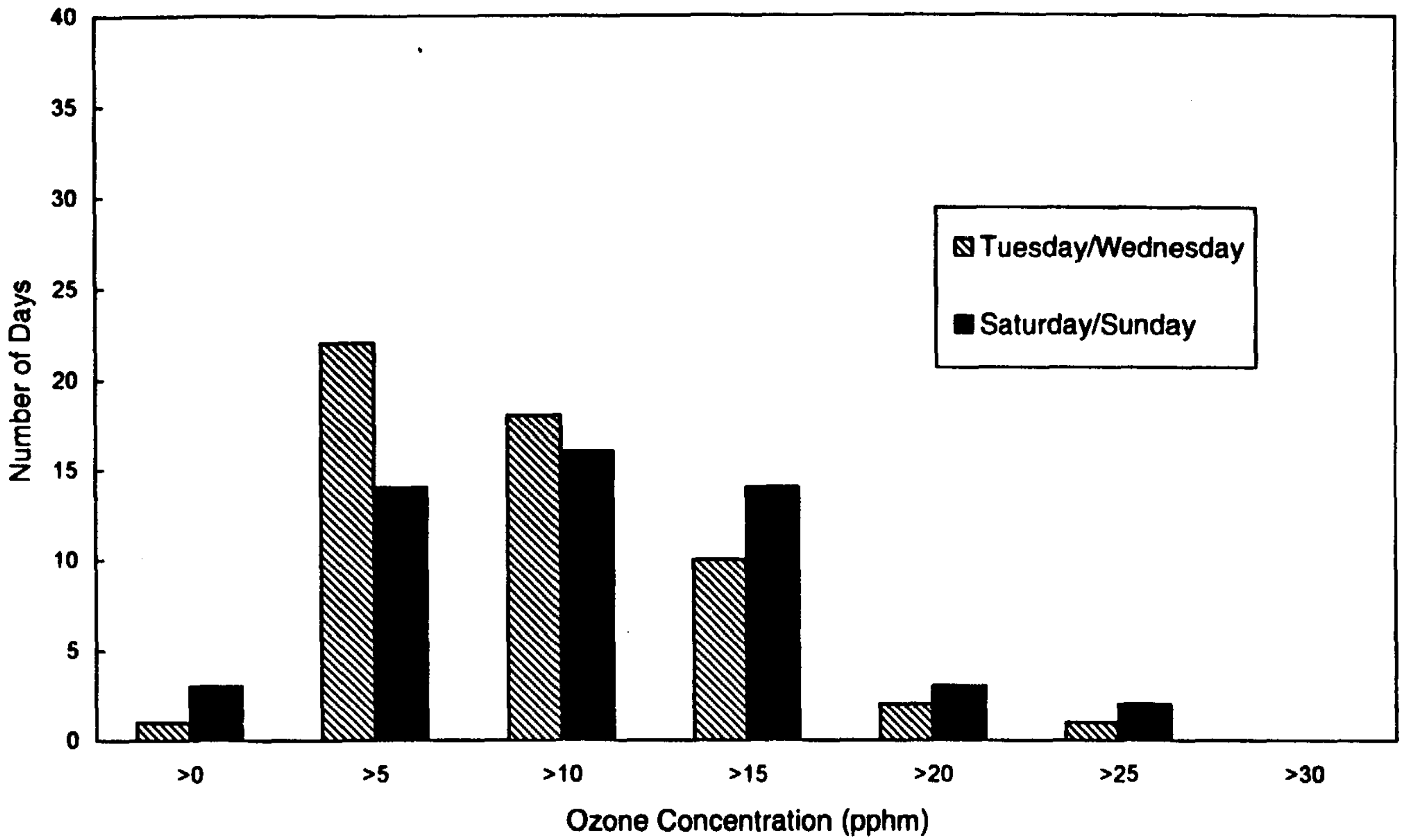

Figure 6-21. Distribution of daily ozone maxima (May 1 - Oct. 31, 1990) for Riverside.

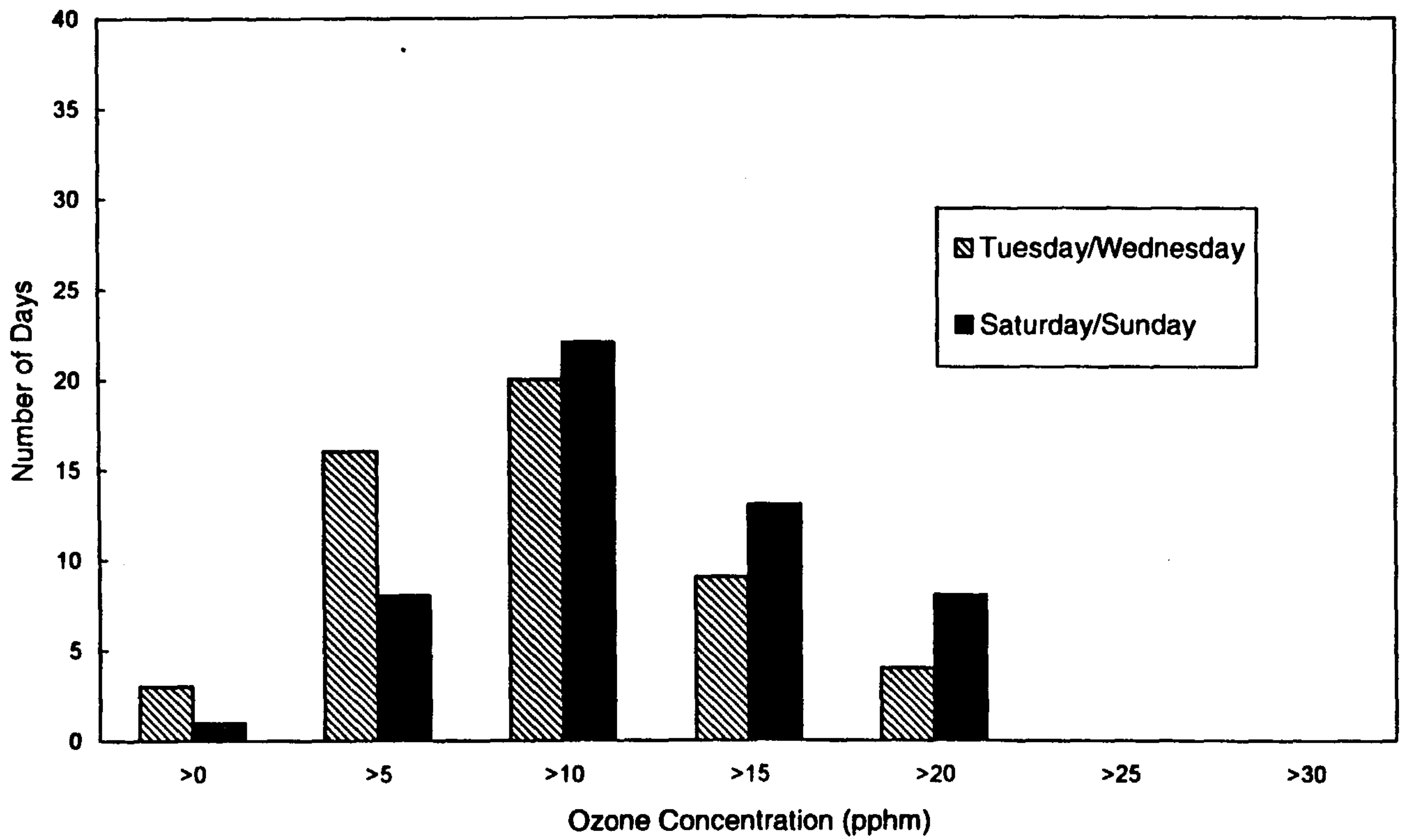

Figure 6-22. Distribution of daily ozone maxima (May 1 - October 31, 1991) for Riverside.

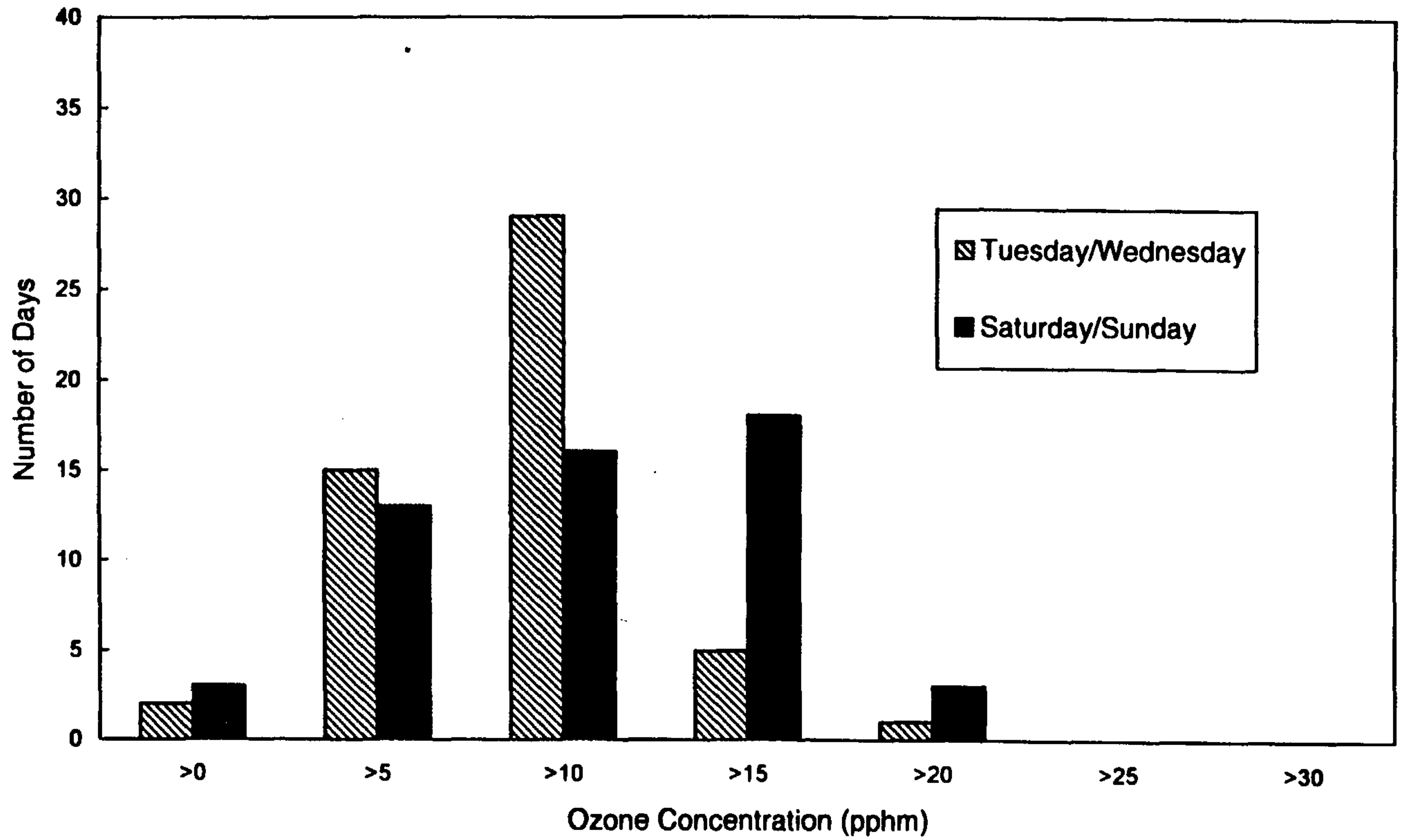

Figure 6-23. Distribution of daily ozone maxima (May 1 - October 31, 1992) for Riverside.

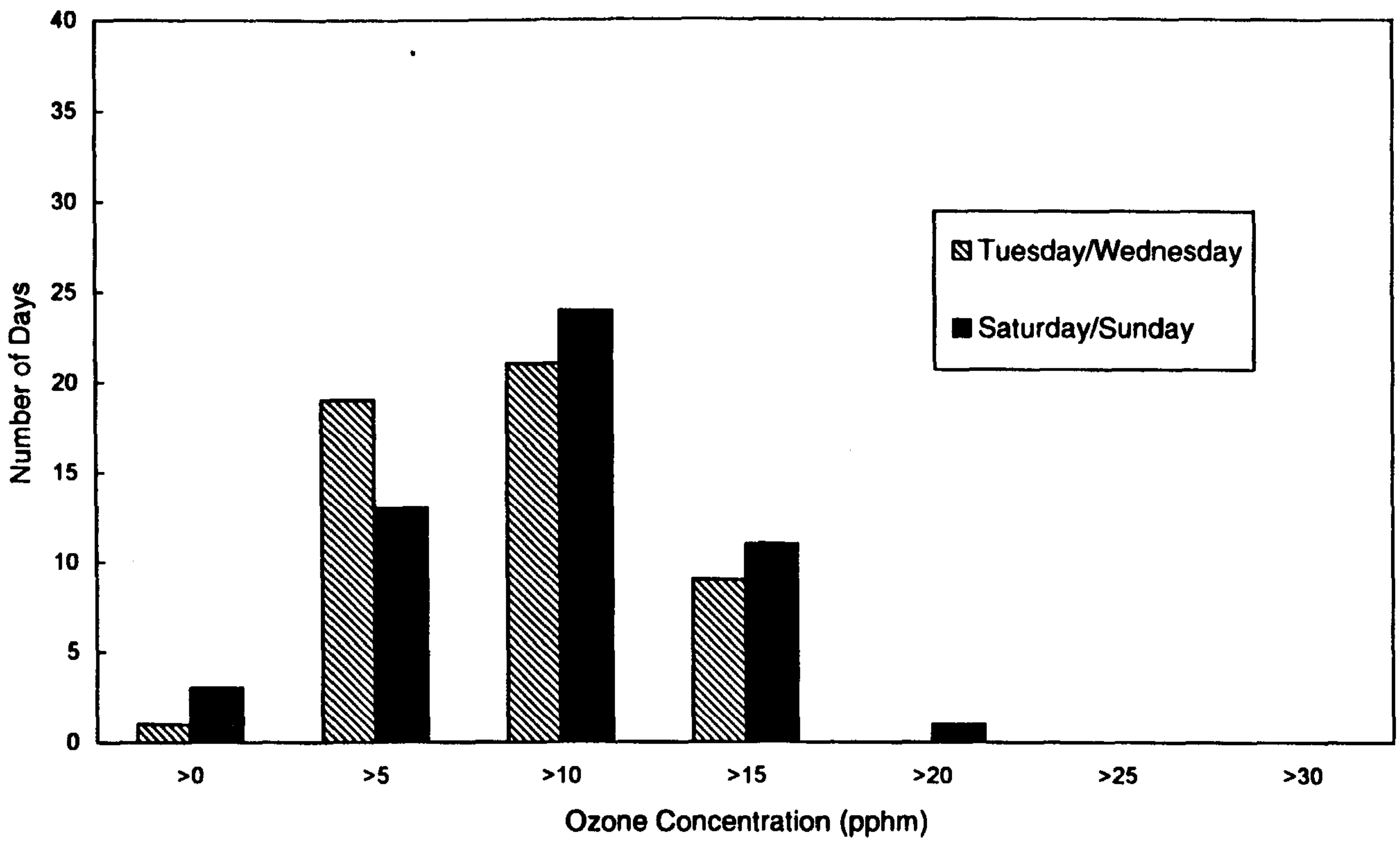

Figure 6-24. Distribution of daily ozone maxima (May 1 - October 31, 1993) for Riverside.

maximum concentrations were more frequent on the weekdays. Enhancement of this difference appeared to occur in the later years. Similar trends, are seen in the 1986-93 data for Central LA and, to a lesser degree, Riverside (Figures 6-1 through 6-8 and Figures 6-17 through 6-24, respectively).

A summary of WD/WE differences in daily ozone maxima by subregion is shown in Table 6-2 for the two four year periods (where weekday was defined as Wednesday and Thursday consistent with Horie, 1988). As shown elsewhere, for all subregions both WD and WE ozone was lower in the second four-year period. While WE minus WD differences were not statistically significant (by the t-test) for the 1986-89 period, these differences were significant at the 95% confidence level for all subregions except the Crestline station (*i.e.*, Mountain subregion) for the 1990-93 period. These results show that WD/WE differences in the daily ozone maxima increased between periods I and II in all subregions. In particular, there were substantially greater decreases in peak ozone on weekdays between the two periods then for weekend days.

6.4 Ozone First Stage Alerts and Cumulative Hourly Exposure for Weekdays vs. Weekend Days

As defined by the SCAQMD, a first stage alert for ozone is declared if the hourly-average ozone concentration equals or exceeds 20 pphm at any station in the SoCAB. Here we compare the number of ozone first stage alerts on weekdays and weekends days for the stations at Central LA, Azusa, and Riverside.

Figures 6-25 through 6-27 show the distribution of ozone first stage alerts by day of the week for these three stations for the entire eight-year period 1986-93. A greater number of ozone first stage alerts occurred on Saturday/Sunday than on weekdays at the Azusa station, and to some degree at the Central LA station.

Figures 6-28 through 6-30 show the number of ozone first stage alerts for each day of the week for each year during the period 1986-93 for the same three stations. A general decline is seen in the number of ozone first stage alerts for all days of the week over the eight-year period. The Azusa and Central LA stations appear to have experienced greater declines than did the Riverside station.

Table 6-2. Average weekday/weekend differences in daily ozone maxima between period I (1986-89) and period II (1990-93) in subregions of the South Coast Air Basin.

Subregion	WD[a] (pphm)	WE[b] (pphm)	WE-WD (pphm)	t-statistic
San Gabriel				
P - I	12.9	13.5	0.6	0.9
P - II	10.2	12.6	2.4	4.3[c]
Percent change	-21%	-7%		
Inland				
P - I	11.9	11.7	-0.2	-0.4
P - II	8.9	10.5	1.6	3.6[c]
Percentage change	-25%	-10%		
Inland Valley				
P - I	13.5	12.9	-0.6	-1
P - II	11.0	12.5	1.5	3.0[c]
Percentage change	-19%	-3%		
Coastal				
P - I	5.9	6.5	0.6	2.0
P - II	5.3	6.0	0.7	2.6[c]
Percentage change	-10%	-8%		
Metropolitan				
P - I	7.9	8.9	1.0	2.4
P - II	6.7	8.3	1.6	4.3[c]
Percentage change	-15%	-7%		
Mountain				
P - I	14.3	13.9	-1.2	-2.2
P - II	12.4	12.8	0.4	0.9
Percentage change	-13%	-8%		

[a] Typical weekdays were chosen to be Wednesday and Thursday.
[b] Weekend days.
[c] Significant differences: 95% confidence level.

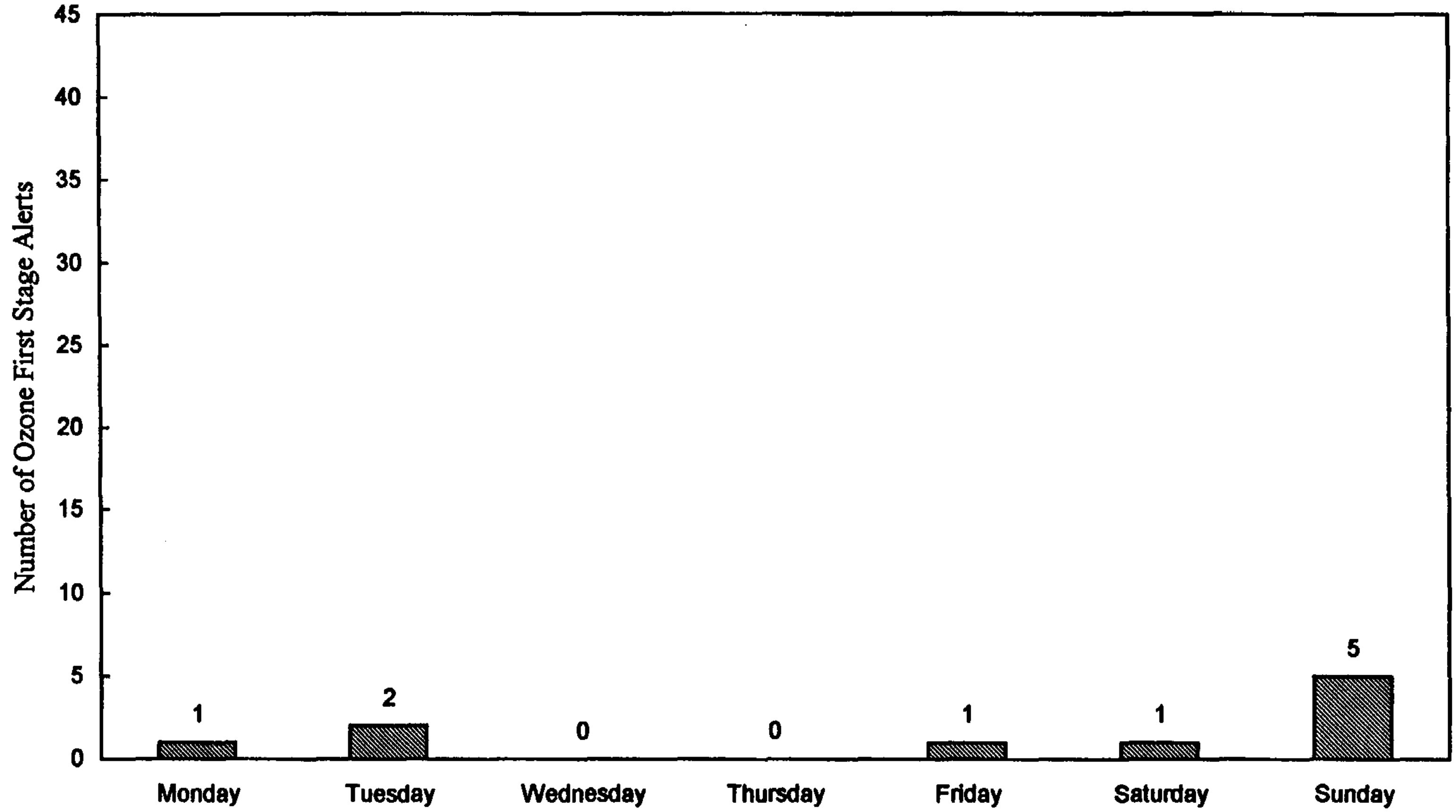

Figure 6-25. Total number of ozone first stage alerts for the period 1986-1993 (May 1 - Oct 31) for Central Los Angeles, by day of the week.

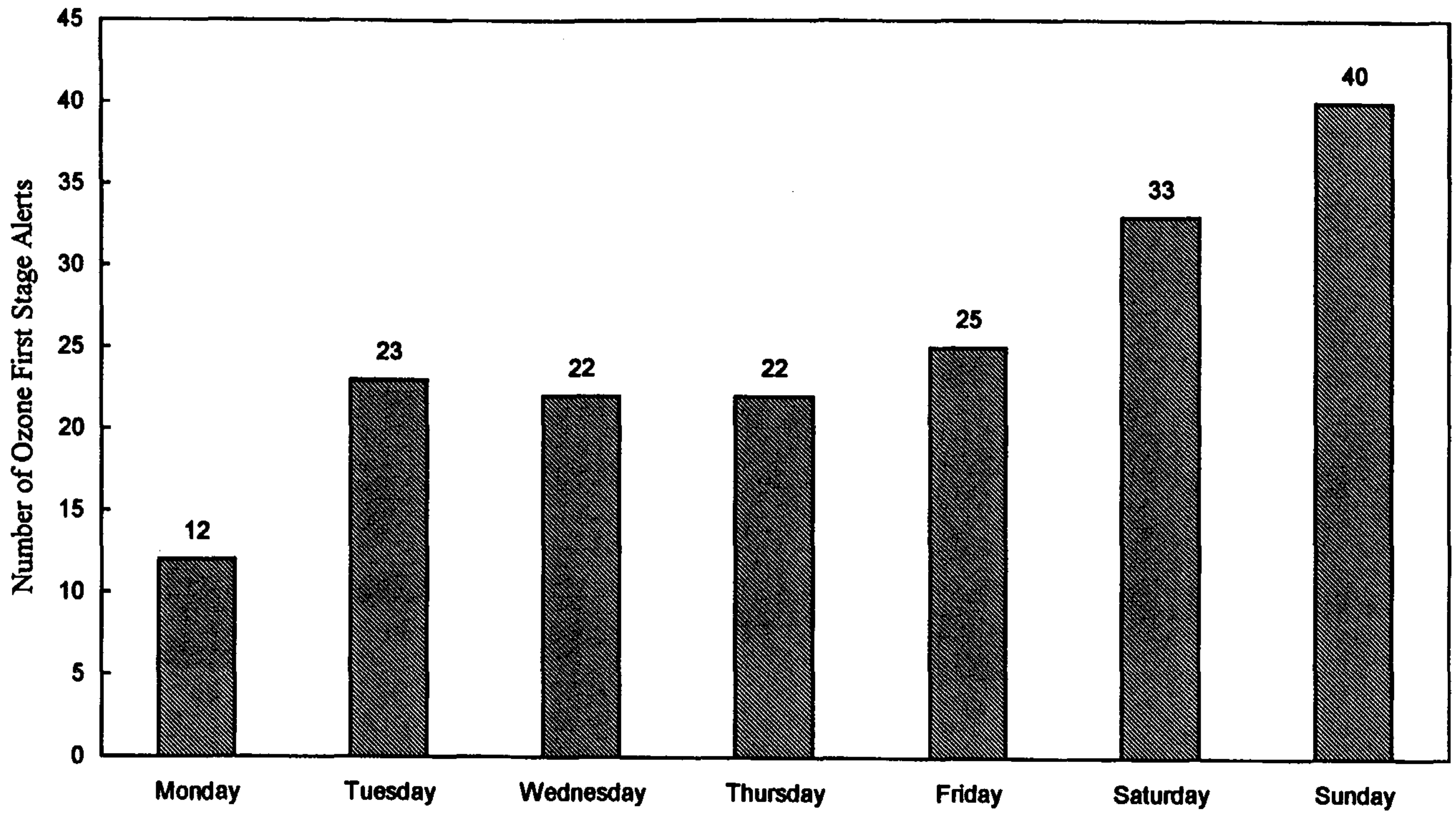

Figure 6-26. Total number of ozone first stage alerts for the period 1986-1993 (May 1 - Oct 31) for Azusa, by day of the week.

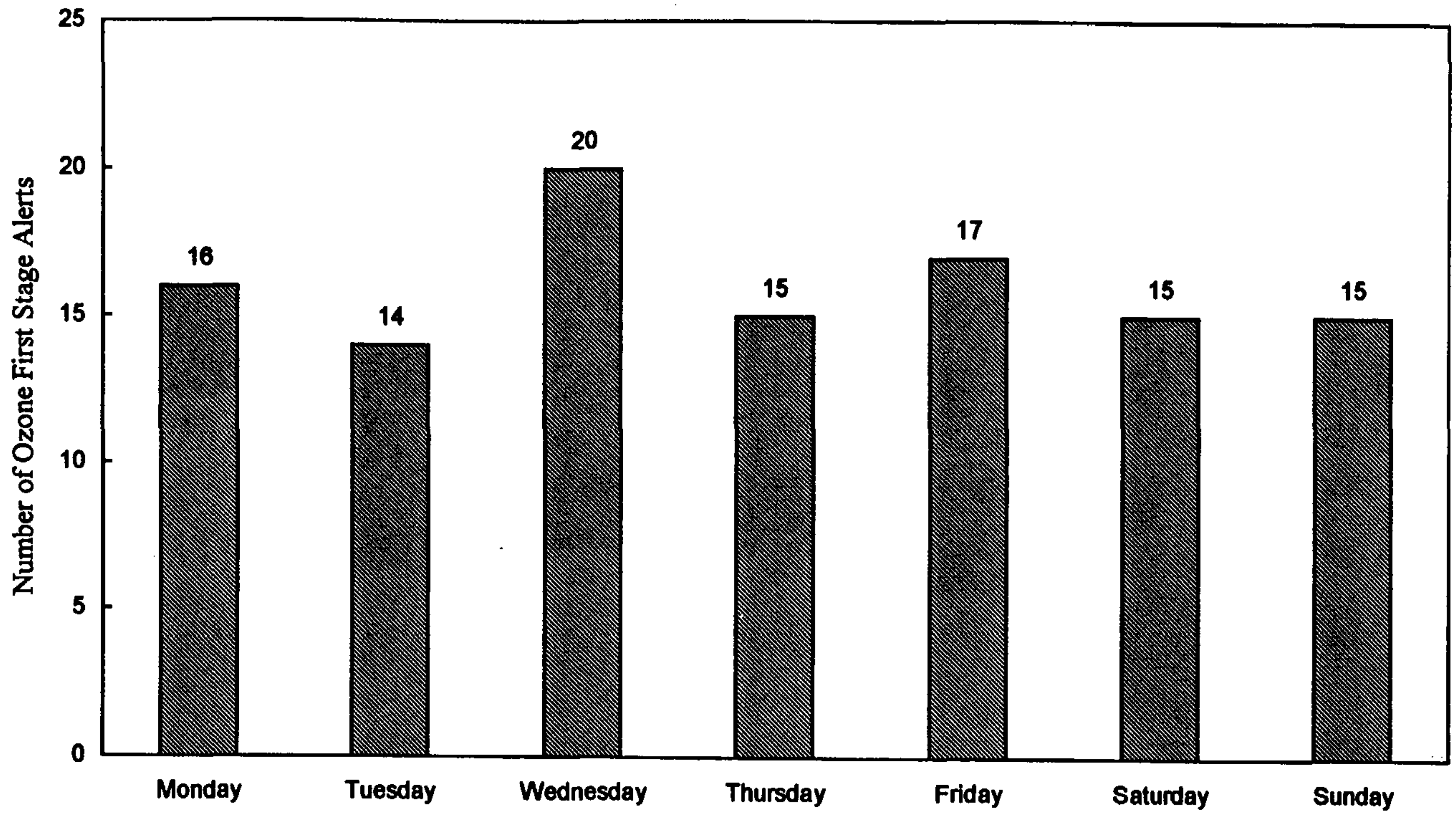

Figure 6-27. Total number of ozone first stage alerts for the period 1986-1993 (May 1 - Oct 31) for Riverside, by day of the week

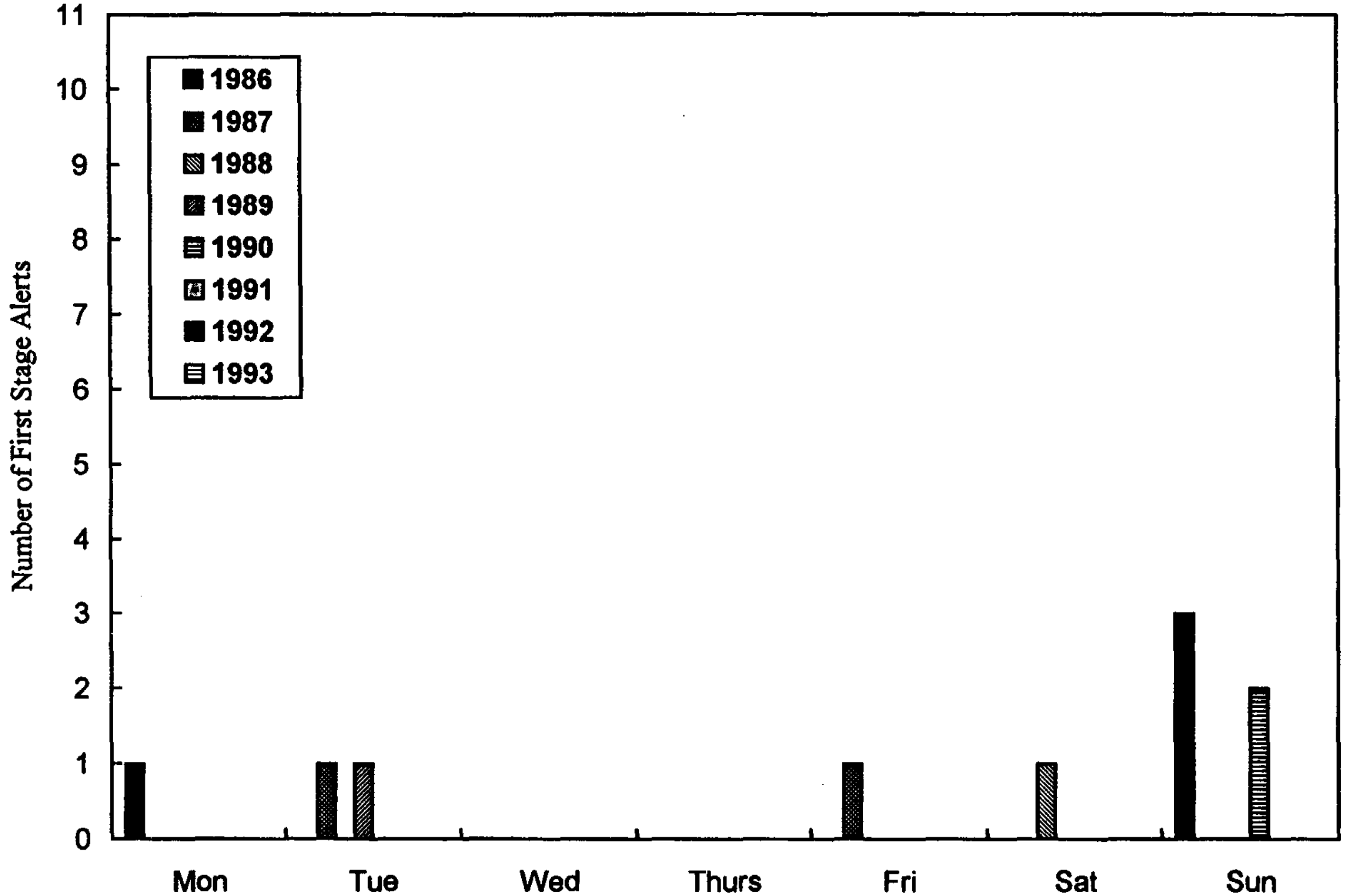

Figure 6-28. Number of ozone first stage alerts (May 1 - October 31) for Central Los Angeles by day of the week for each individual year between 1986 and 1993.

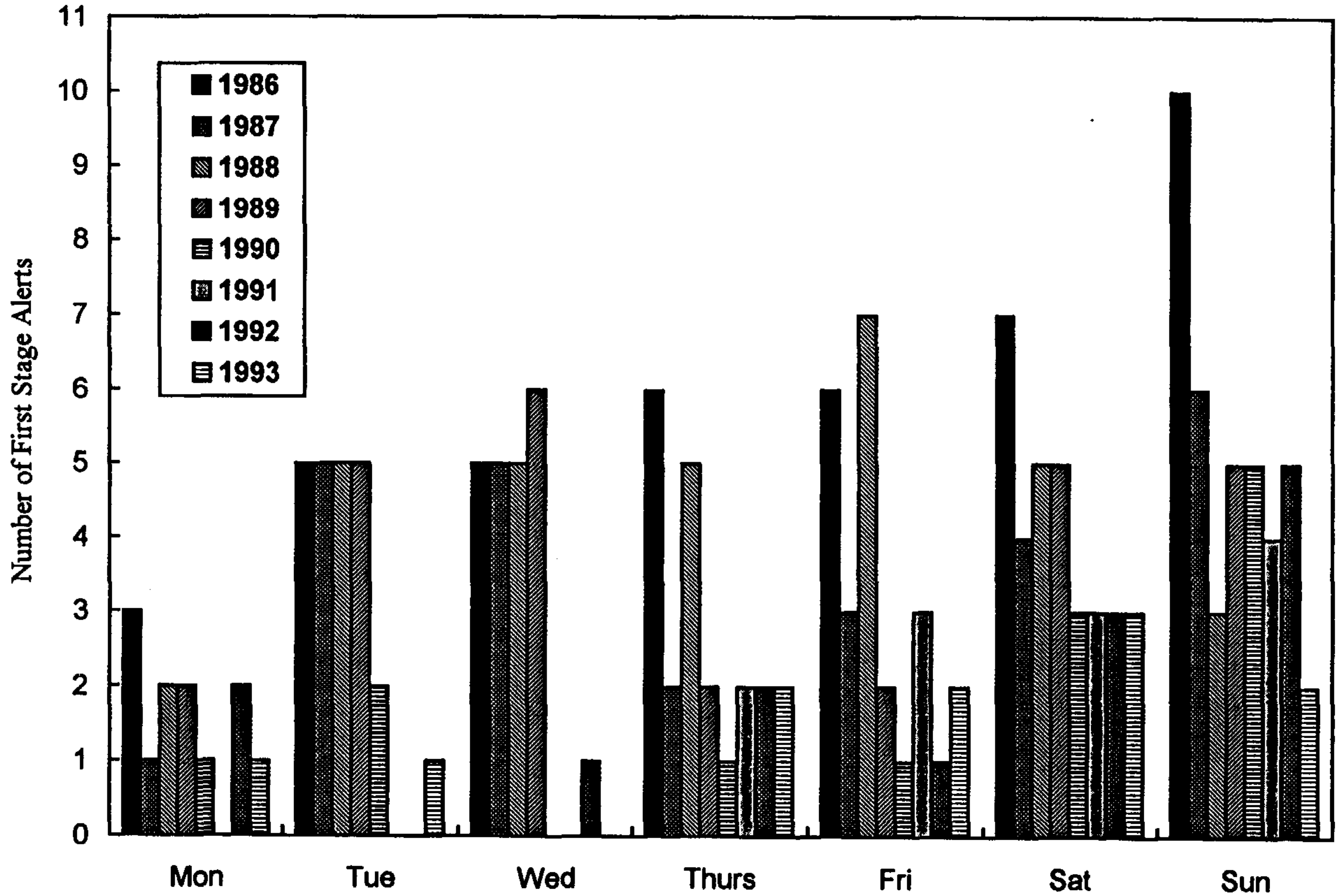

Figure 6-29. Number of ozone first stage alerts (May 1 - October 31) for Azusa by day of the week for each individual year between 1986 and 1993.

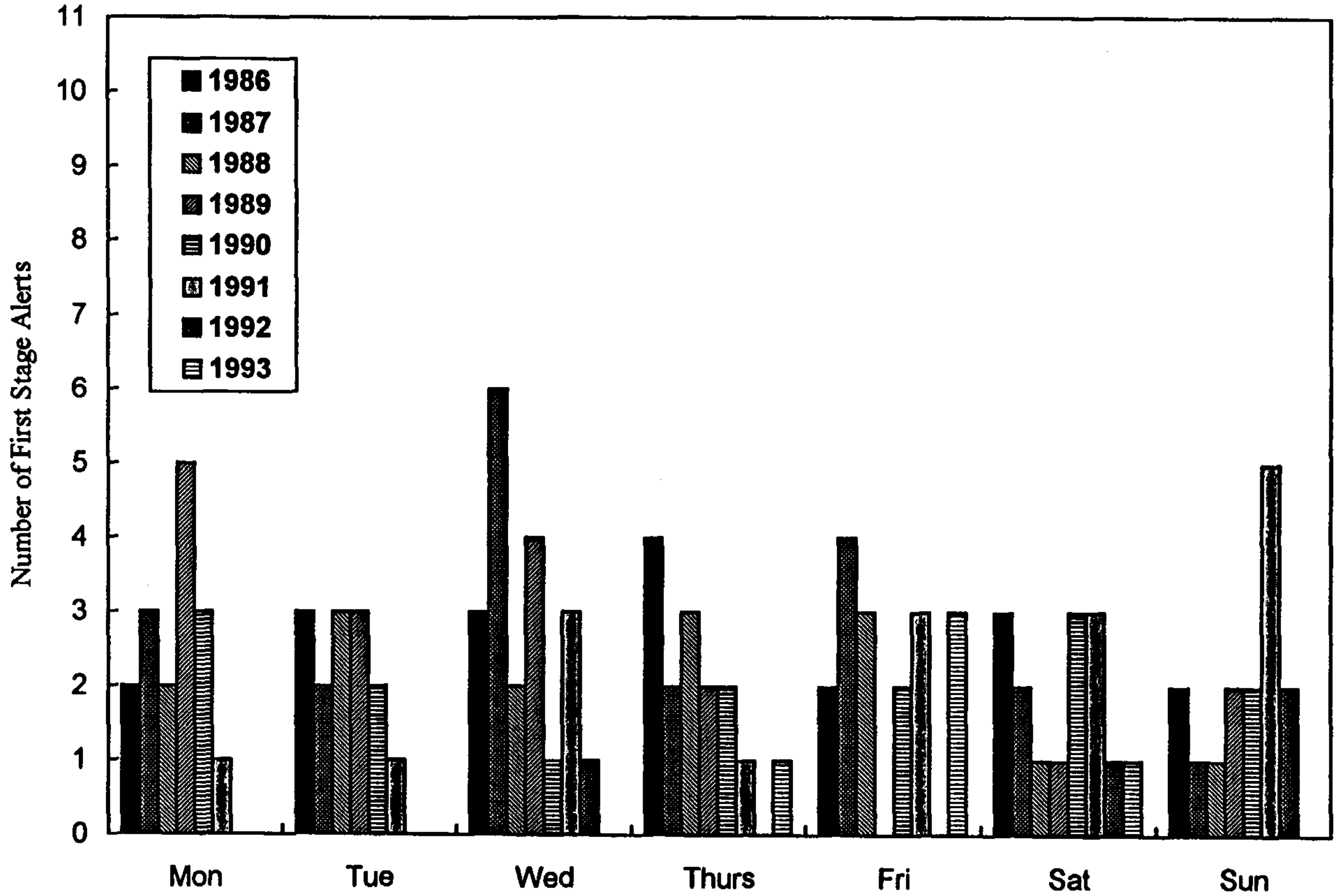

Figure 6-30. Number of ozone first stage alerts (May 1 - October 31) for Riverside by day of the week for each individual year between 1986 and 1993.

The cumulative hourly ozone exposure above the federal standard of 12 pphm was computed for each day of the air pollution season for each of the eight years of interest for the Central LA, Azusa and Riverside stations. The cumulative ozone exposure over the length of the air pollution season was then computed for each day of the week for each year (Figures 6-31 through 6-33). In general, the cumulative ozone exposure decreased over the eight-year period (1986-93) for all days of the week at all three stations. Ozone exceedances for Central LA and Azusa tended to be higher on weekend days than on weekdays, while this was not necessarily true for Riverside.

For the same three stations (Central LA, Azusa and Riverside) we examined by year in the period 1986-93 the number of hours equal to or above the National Ambient Air Quality Standard of 12 pphm. The data are shown in Table 6-3 along with the percentage of total monitoring hours at or above the standard. As can be seen, dramatic decreases in hours above the ozone NAAQS occurred for all three stations over the period between 1986 and 1993.

Table 6-3. Trends in hours equal or above the ozone NAAQS of 12 pphm.

Year	Number of hours with ozone > = 12 pphm			Percentage of total hours		
	Central L.A.	Azusa	Riverside	Central LA	Azusa	Riverside
1986	132	507	467	3	11.5	10.6
1987	103	446	550	2.3	10.1	12.5
1988	82	467	556	1.9	10.6	12.6
1989	94	436	514	2.1	9.9	11.6
1990	95	299	398	2.2	6.8	9.0
1991	73	254	419	1.7	5.8	9.5
1992	60	307	352	1.4	7.0	8.0
1993	21	287	320	0.5	6.5	7.2

* Total number of hours (May 1 - Oct 31) each year = 184*24 = 4416.

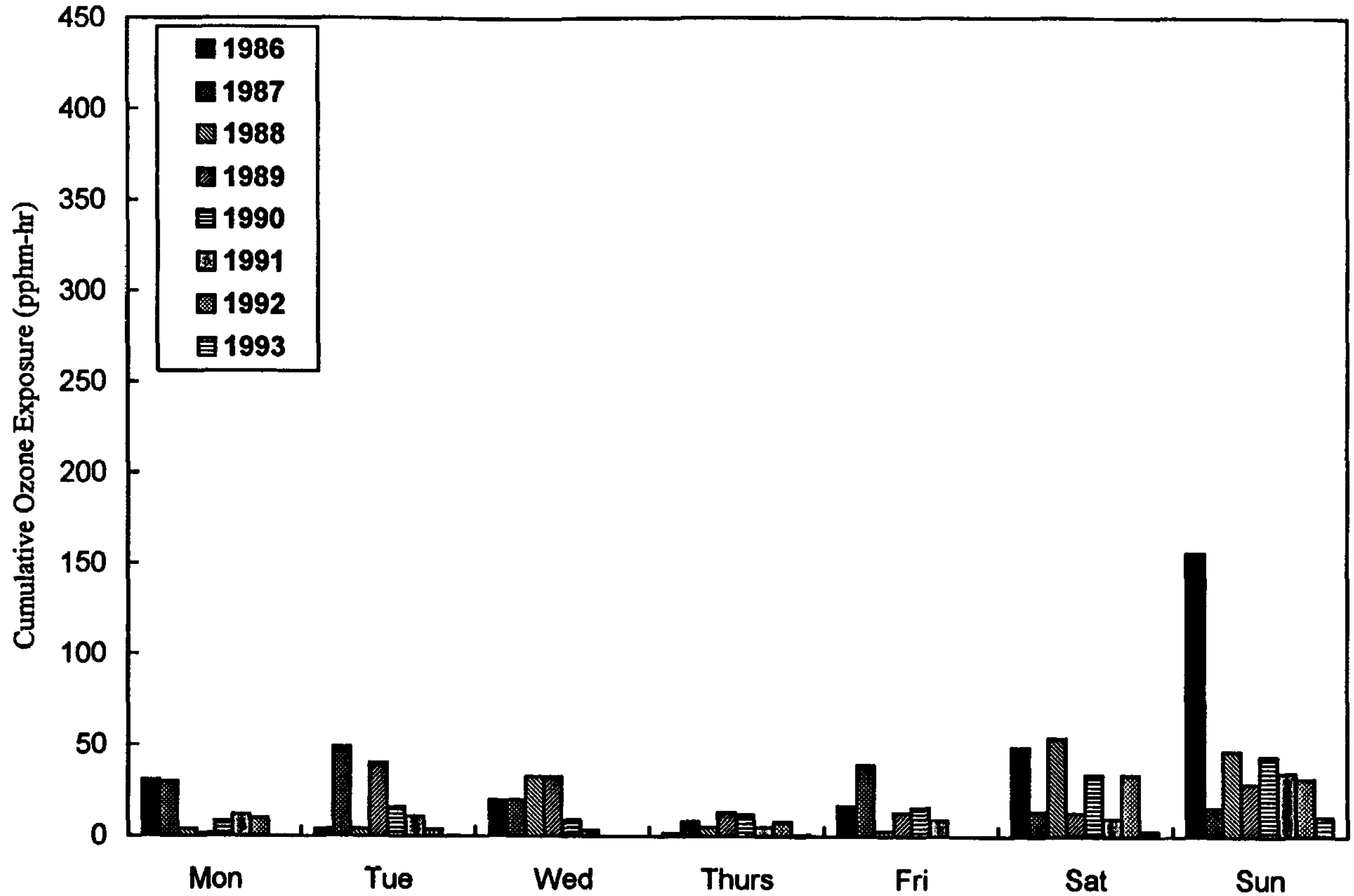

Figure 6-31. Cumulative ozone exposure for concentrations above 12 pphm (May 1 - October 31) for Central Los Angeles, by day of the week for each year between 1986 and 1993.

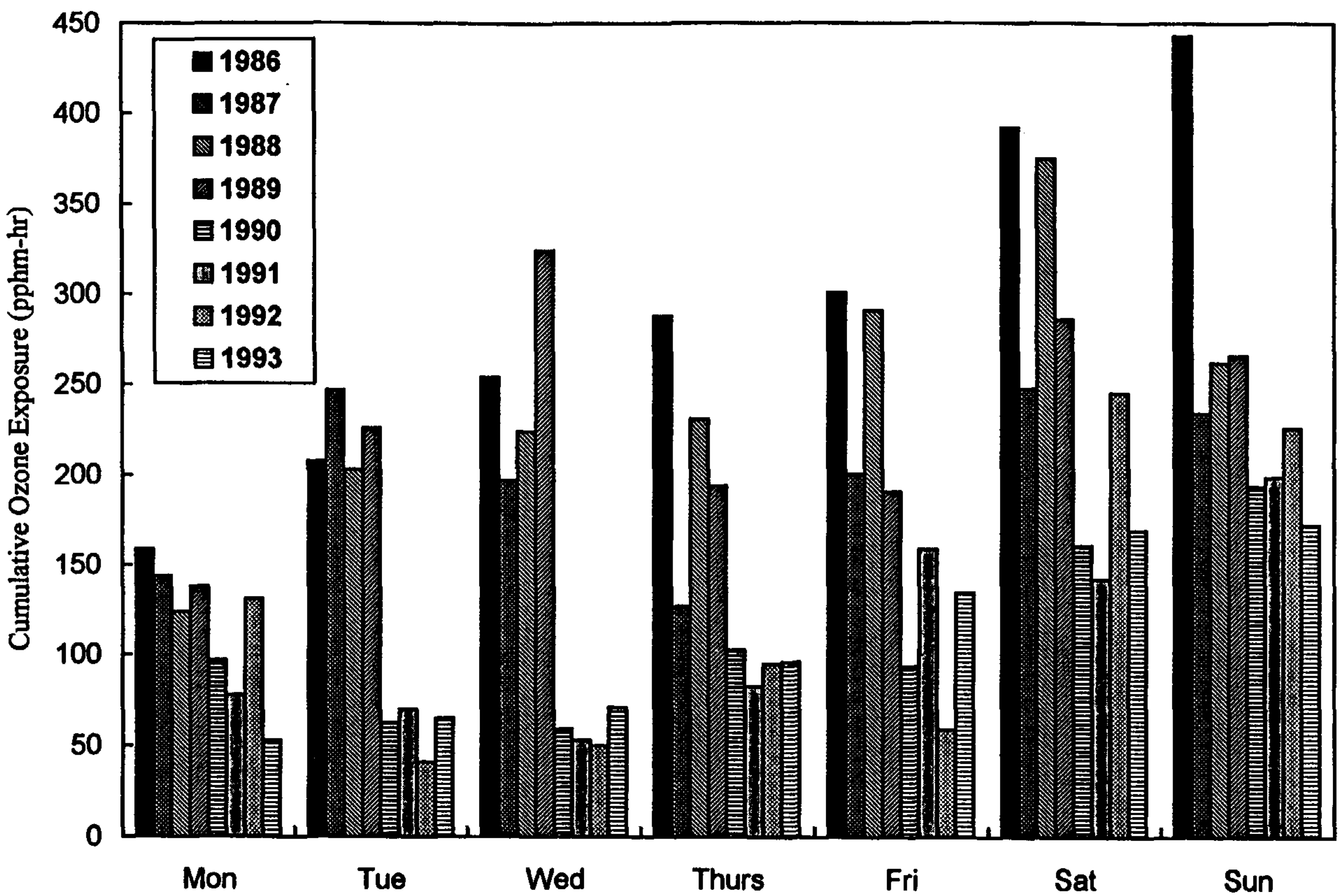

Figure 6-32. Cumulative ozone exposure for concentrations above 12 pphm (May 1 - October 31) for Azusa, by day of the week for each year between 1986 and 1993.

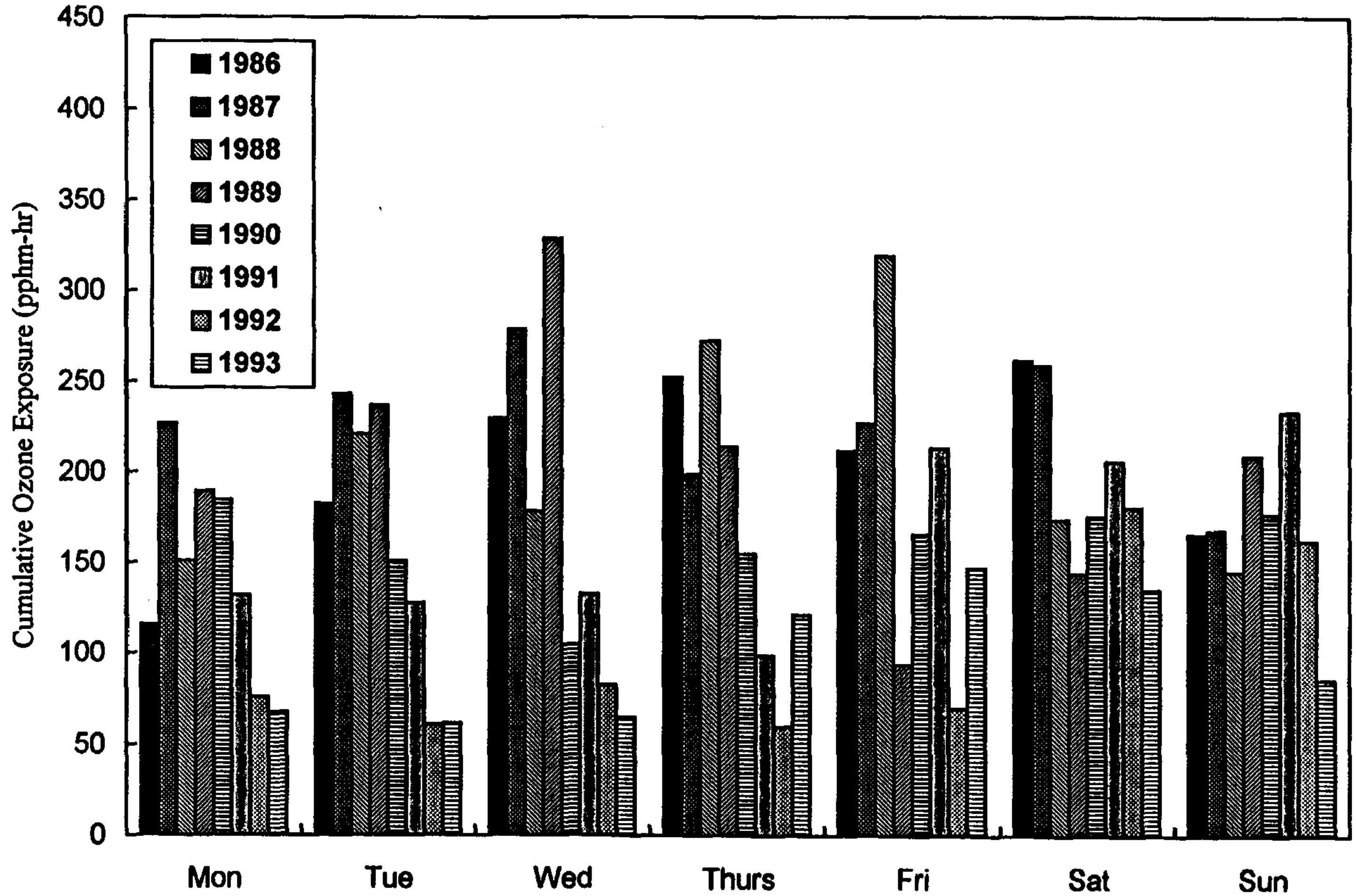

Figure 6-33. Cumulative ozone exposure for concentrations above 12 pphm (May 1 - October 31) for Riverside by day of the week for each year between 1986 and 1993.

6.5 Weekday/Weekend Analyses Using the CART Scheme

The CART scheme developed by Horie (1987) was used to bin the smog season days into the 10 different nodes of the tree in 3 different ways. First, the smog season days for each of the years 1986-93 were individually binned using the CART scheme. Then, all of the smog season days for 1986-89 were treated as one group for binning and those for 1990-93 were treated as a second group. Finally, the weekdays (here represented by Tuesday and Wednesday) and the weekend days (Saturday and Sunday) were separately binned for the two four-year periods 1986-89 and 1990-93. The present discussion focuses on the third of these applications of the CART scheme, the results of which are shown in Table 6-4. However, before proceeding, a *caveat* noted in Chapter 5 should be reiterated. As indicated by Instaweather (1989), if we were to develop a new CART tree for the period of years we are examining, it is quite likely that the nodes would be defined differently than in the CART tree developed by Horie (1987) using meteorological data from 1983-85. Such a task, however, was beyond the scope of the present project.

Several interesting results appear in Table 6-4. First, we see a general increase in mean (daily SoCAB maximum hourly-average) ozone value with node number in Horie's CART scheme. On average, the worst ozone days were defined by node 10, characterizing 6%-8% of the smog season days. However, the standard deviations were sufficiently large that many of the CART nodes cannot simply be considered as statistically distinct from each other. We will further address this issue later in this chapter when we examine the 10 days from each smog season with the highest hourly-average ozone concentrations and their associated CART classifications.

Nonetheless, this type of application of the CART scheme does allow us to make some comparisons between weekdays and weekend days, and between the two groups of smog seasons, in terms of the representative daily SoCAB maximum hourly-average ozone concentration under similar meteorological conditions. If we first compare 1986-89 weekdays with 1986-89 weekend days, we find little difference in the mean ozone values regardless of CART node classification. Of course, these results could be misleading if, for example, the two weekend days cannot be treated as being similar in

Table 6-4. The application of Horie's CART scheme to weekdays and weekend days during 1986-89 and 1990-93. "-1.0" indicates no data.

1986-89 Weekdays (Tuesday and Wednesday)

Node	Sum	Mean	Std. Dev.	Percent
1	0	-1.0	-1.0	0.0
2	23	8.5	2.6	11.0
3	0	-1.0	-1.0	0.0
4	12	11.3	3.5	5.7
5	40	14.7	4.1	19.1
6	60	19.5	3.8	28.7
7	8	19.0	4.0	3.8
8	46	20.8	4.8	22.0
9	7	22.4	3.2	3.3
10	13	26.4	4.7	6.2

1986-89 Weekend Days (Saturday and Sunday)

Node	Sum	Mean	Std. Dev.	Percent
1	0	-1.0	-1.0	0.0
2	32	9.1	2.7	15.2
3	0	-1.0	-1.0	0.0
4	11	9.9	2.8	5.2
5	40	14.3	3.2	19.0
6	66	19.1	4.0	31.4
7	10	18.2	3.0	4.8
8	32	22.2	3.3	15.2
9	6	22.7	4.3	2.9
10	13	27.0	3.9	6.2

1990-93 Weekdays (Tuesday and Wednesday)

Node	Sum	Mean	Std. Dev.	Percent
1	0	-1.0	-1.0	0.0
2	25	9.0	3.2	11.9
3	0	-1.0	-1.0	0.0
4	19	9.6	1.7	9.0
5	59	12.2	3.0	28.1
6	38	15.8	3.0	18.1
7	4	14.2	2.5	1.9
8	36	16.7	3.9	17.1
9	12	19.1	2.6	5.7
10	17	22.1	4.2	8.1

1990-93 Weekend Days (Saturday and Sunday)

Node	Sum	Mean	Std. Dev.	Percent
1	0	-1.0	-1.0	0.0
2	21	8.7	2.8	10.2
3	0	-1.0	-1.0	0.0
4	20	11.0	2.3	9.7
5	43	13.3	3.7	20.9
6	61	17.6	4.4	29.6
7	7	16.9	2.7	3.4
8	29	19.2	2.6	14.1
9	9	19.9	2.0	4.4
10	16	23.4	3.3	7.8

Sum = No. of smog season days.
Mean = Mean ozone concentration in pphm.
Std. Dev. = Standard deviation in mean ozone concentration.
Percent = Percent of smog season days.

characteristic peak ozone value. There is in fact some evidence this might be the case, as we will discuss later in this chapter. Differences appear somewhat larger when we compare mean ozone values for 1990-93 weekdays with 1990-93 weekend days, especially those for nodes 6, 7, and 8. These nodes are distinguished from nodes 9 and 10 primarily by having a lower value of the 900 mb temperature.

Finally, we compared 1986-89 weekdays with 1990-93 weekdays and 1986-89 weekend days with 1990-93 weekend days. Here we see a general decrease in ozone values (except for the characteristically low-ozone concentration node 2 where a slight increase occurs); interestingly, though, for all of these CART nodes there was a larger decrease for weekdays than for weekend days.

6.6 Examination of Ten Days with Highest Hourly-Average Ozone Concentrations: 1986-89 vs. 1990-93

6.6.1 All Days

To further investigate the trends noted from application of the CART scheme, we examined the means of the ten highest daily hourly-average ozone concentrations for each of the four-year periods for each of the stations for which we have data (Table 6-5). In other words, we examined the trends as seen from the worst ozone days. We recognize that in limiting our examination to the ten days with the highest daily maximum hourly average ozone concentrations our results may not be as representative as those obtained from using a larger sample size (*e.g.*, 30 days) as is commonly used in ARB's Technical Support Division. We believe progress towards ozone standard attainment in the SoCAB is best measured by focusing on the worst ozone episodes. Therefore, we sacrificed the robustness offered by the larger sample size to gain the sensitivity derived from examination of only the worst days.

For 30 of the 32 stations listed (5 outside the SoCAB boundaries), the mean of the ten highest daily ozone concentrations for 1990-93 was less than that for 1986-89 (the two exceptions were Hemet and Lake Gregory/Crestline, at the far east end of the SoCAB, where slight increases occurred). If we now consider just the subset of stations where the

Table 6-5. Means and standard deviations of the ten highest hourly average ozone concentrations for 32 stations for the period 1986-90, and for the period 1990-93. Absolute and percentage differences in means are also shown. Ozone concentrations reported in pphm.

Station	M1	SD1	M2	SD2	M2-M1	% Decrease
Anaheim	21.9	2.4	18.9	2.7	-3.0	13.7
La Habra	24.1	2.2	19.8	0.9	-4.3	17.8
El Toro	18.8	2.3	17.8	2.5	-1.0	5.3
Los Alamitos	16.6	2.6	15.8	0.9	-0.8	4.8
Palm Springs*	18.3	0.8	16.8	0.8	-1.5	8.2
Hemet	17.3	1.1	17.7	1.8	0.4	-2.3
Riverside	26.8	1.2	25.2	1.8	-1.6	6.0
Perris	20.6	1.2	19.8	0.4	-0.8	3.9
Banning	23.2	1.4	19.7	0.9	-3.5	15.1
Norco	24.2	1.1	20.4	1.3	-3.8	15.7
Barstow*	14.3	0.7	12.4	0.5	-1.9	13.3
Upland	29.0	2.5	25.1	1.7	-3.9	13.4
Lake Gregory/ Crestline	26.3	1.6	26.7	2.8	0.4	-1.5
Trona*	11.0	1.2	10.4	0.7	-0.6	5.5
Adobe*	12.8	0.9	12.7	0.8	-0.1	0.8
Fontana	28.7	2.0	25.6	1.6	-3.1	10.8
Hesperia*	23.4	1.8	20.6	2.6	-2.8	12.0
San Bernardino	27.4	1.7	23.7	2.1	-3.7	13.5
Azusa	30.1	1.5	24.9	1.3	-5.2	17.3
Burbank	23.3	1.8	20.8	0.9	-2.5	10.7
Long Beach	15.1	1.2	12.7	1.1	-2.4	15.9
Reseda	21.9	1.3	19.1	1.2	-2.8	12.8
Pomona	26.2	1.7	23.2	0.8	-3.0	11.5
Whittier	23.4	2.6	17.9	0.9	-5.5	23.5
Lynwood	18.2	2.6	13.1	1.4	-5.1	28.0
Pico Rivera	26.0	2.1	21.7	2.5	-4.3	16.5
Central L.A.	20.8	1.8	17.5	1.6	-3.3	15.9
Pasadena	26.9	1.1	22.8	1.3	-4.1	15.2
Newhall	26.1	1.9	22.1	1.2	-4.0	15.3
West L.A.	20.7	3.0	15.6	1.3	-5.1	24.6
Hawthorne	14.8	3.4	11.4	0.5	-3.4	23.0
Glendora	33.2	1.2	28.9	1.9	-4.3	13.0

M1 = Mean of 10 highest ozone concentrations during 1986-89.
M2 = Mean of 10 highest ozone concentrations during 1990-93.
SD1 = Standard deviation of 10 highest ozone concentrations during 1986-89.
SD2 = Standard deviation of 10 highest ozone concentrations during 1990-93.
* Stations located outside SoCAB boundries.

magnitude of the decrease in means exceeded the sum of the standard deviations, we found that only 1 of these 10 stations (Banning) was in the far east end of the SoCAB. Of the remainder, 5 stations were in the Coastal/Metropolitan subregions and 3 were in the San Gabriel Valley. Thus the most significant ozone decreases between the two four-year periods occurred in the western or middle portions of the Basin. An isopleth plot illustrating these results is shown in Figure 6-34. The most pronounced decrease in peak ozone occurred in the western portion of the Basin, corresponding generally to the area of maximum decrease in NO_x over this same eight year period (see Figure 6-35).

Data for the individual stations were then aggregated by subregion as shown in Table 6-6 to obtain the average percent decrease in the top ten ozone concentrations between 1986-89 and 1990-93 for each subregion. Apart from the Mountain subregion which included only the Crestline/Lake Gregory station and showed a 1.5% increase, all other subregions showed significant average decreases in peak ozone levels between the two periods, ranging from about 8% decrease for the Inland Valley to decreases of about 15% for the Coastal, Metropolitan, San Gabriel Valley and Inland subregions.

6.6.2 Weekdays and Weekend Days: Ozone Trends Between 1986-89 and 1990-93

Similar analyses to those shown in Table 6-5 were constructed for just weekdays (Tuesday and Wednesday) and for just weekend days (Saturday and Sunday). Results of these analyses are summarized by subregion of the SoCAB in Table 6-7. Subregions were designated following Horie (1988) though, as discussed earlier, we chose representative stations for each subregion based on the degree of completeness of the data record during our study period (1986-93).

With the exceptions of weekend days at Hemet and at Perris, we found that peak daily ozone values decreased throughout the Basin on both weekdays and weekend days. In the Coastal subregion, however, the decrease in the ten highest ozone concentrations on weekdays was less than that on weekend days (at all four of the stations used for this region), while the reverse was generally true for all of the other subregions. We also found the ratio of the magnitude of the decrease on weekdays to that on weekend days tended to increase with distance from the coast. Specifically, for the Metropolitan

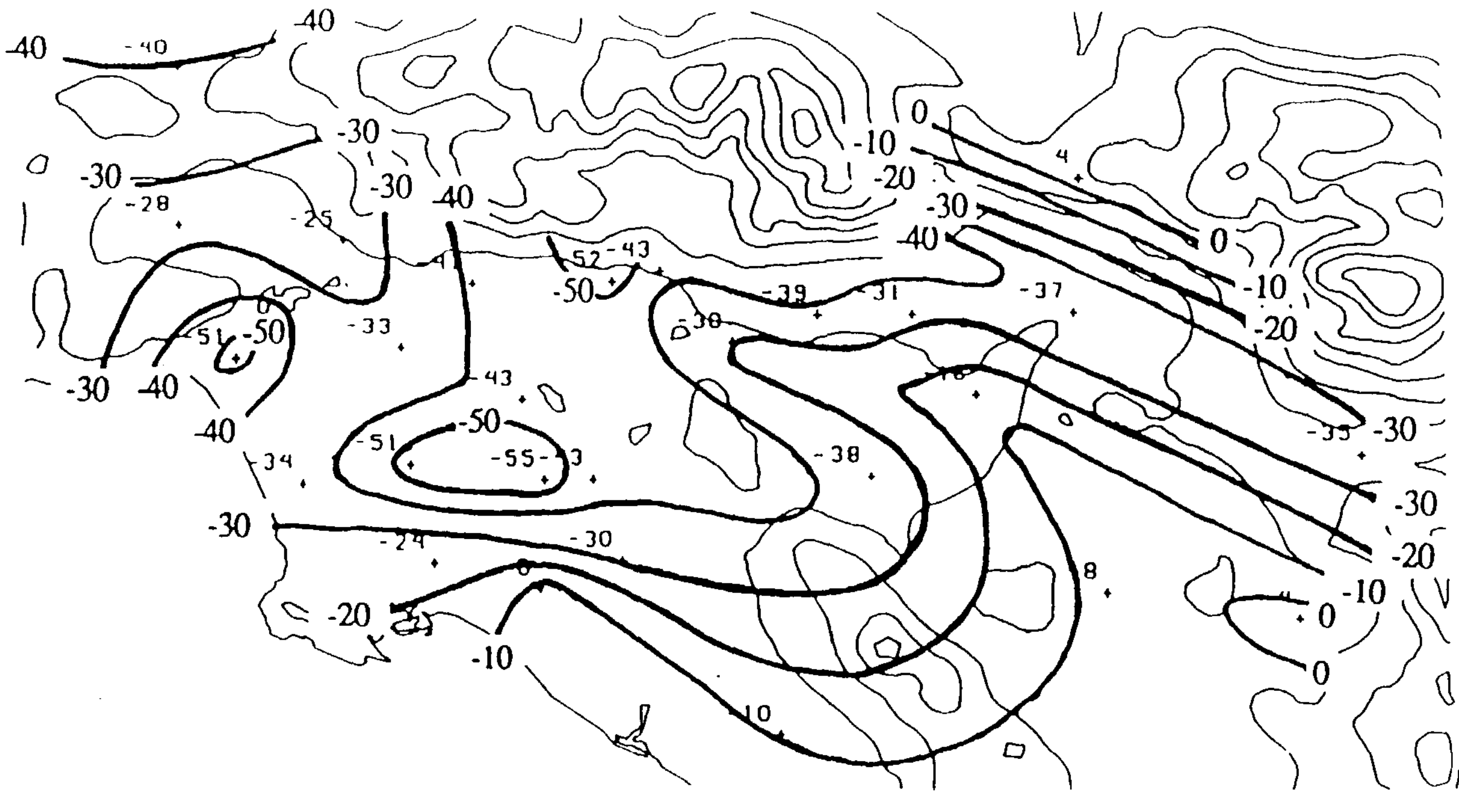

Figure 6-34. Changes in means of the ten highest daily ozone concentrations (ppb) between 1986-89 and 1990-93 by station within the SoCAB. Negative values indicate lower ozone values in the latter period.

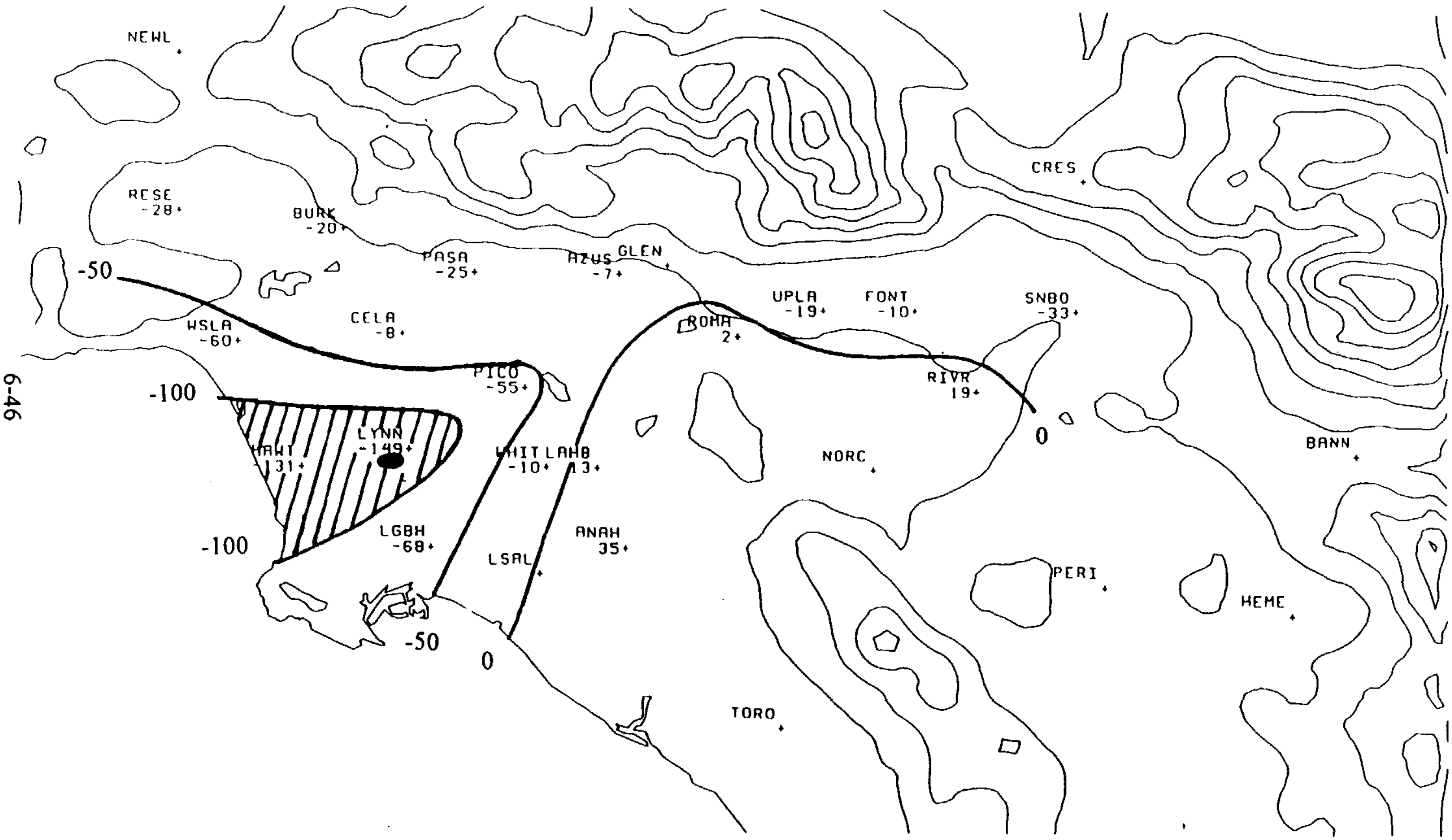

Figure 6-35. Isopleth diagram for change in ambient 5-8 am (PST) NO_x concentration (ppb) from 1986-89 to 1990-93 for top ten O_3 days in those periods.

Table 6-6. Percentage changes in the means of the ten highest daily ozone maximum concentrations between 1986-89 and 1990-93 by subregion.

Subregion/Station	M1	M2	% decrease	Subregion % decrease
Coastal				
Hawthorne	14.8	11.4	23.0	
Long Beach	15.1	12.7	15.9	17.1
Los Alamitos	16.6	15.8	4.8	
West Los Angeles	20.7	15.6	24.6	
Metropolitan				
Anaheim	21.9	18.9	13.7	
Burbank	23.3	20.8	10.7	
Central LA	20.8	17.5	15.9	
El Toro	18.8	17.8	5.3	16.0
La Habra	24.1	19.8	17.8	
Lynwood	18.2	13.1	28.0	
Pico Rivera	26.0	21.7	16.5	
Reseda	21.9	19.1	12.8	
Whittier	23.4	17.9	23.5	
San Gabriel Valley				
Azusa	30.1	24.9	17.3	
Glendora	33.2	28.9	13.0	
Pasadena	26.9	22.8	15.2	14.2
Pomona	26.2	23.2	11.5	
Inland				
Norco	24.2	20.4	15.7	14.6
Upland	29.0	25.1	13.4	
Inland Valley				
Banning	23.2	19.7	15.1	
Fontana	28.7	25.6	10.8	
Hemet	17.3	17.7	-2.3	7.8
Perris	20.6	19.8	3.9	
Riverside	26.8	25.2	6.0	
San Bernardino	27.4	23.7	13.5	
Mountain				
Crestline	26.3	26.7	-1.5	-1.5

M1 = Mean of 10 highest ozone concentrations during 1986-89.

M2 = Mean of 10 highest ozone concentrations during 1990-93.

Table 6-7. Ozone trends for weekdays (WD) and for weekend days (WE) at stations in the SoCAB. Ozone concentrations reported in pphm.

Subregion/Station	WD	WE
Coastal		
West L.A.	-3.2	-4.5
Hawthorne	-0.6	-3.1
Long Beach	-1.3	-1.7
Los Alamitos	-0.7	-1.4
Metropolitan		
Anaheim	-3.4	-0.5
La Habra	-4.7	-2.9
El Toro	-1.3	-0.5
Burbank	-5.3	-2.1
Reseda	-3.5	-2.3
Whittier	-3.3	-3.9
Lynwood	-2.8	-4.8
Pico Rivera	-5.9	-4.2
Central L.A.	-4.5	-2.1
San Gabriel Valley		
Azusa	-7.4	-3.2
Pasadena	-6.2	-2.6
Glendora	-5.6	-3.4
Inland		
Norco	-4.6	-3.1
Upland	-4.9	-1.5
Pomona	-2.9	-1.9
Inland Valley		
Hemet	-2.1	1.0
Riverside	-3.2	-1.5
Perris	-1.5	0.4
Banning	-3.2	-0.6
Fontana	-4.1	-2.1
San Bernardino	-5.8	-1.9
Mountain		
Lake Gregory/Crestline	-1.4	-0.8

M1 = Mean of the 10 highest ozone concentrations during 1986-89.
M2 = Mean of the 10 highest ozone concentrations during 1990-93.
WD = M2-M1 for Tuesdays and Wednesdays
WE = M2-M1 for Saturdays and Sundays.

subregion, the ratio of the mean weekday decrease to the mean weekend day decrease was 1.4, while for the San Gabriel Valley subregion it was 2.0, for the Inland subregion it was 1.9, and for the Inland Valley subregion it was 2.7.

6.6.3 Weekdays vs. Weekend Days: Ozone Differences Within Periods

Here we considered the difference in ten highest ozone concentrations between weekdays and weekend days for each of the two four-year periods (Table 6-8). The subregions and stations are the same as in Table 6-7.

For the period 1986-89, the mean of the ten highest daily ozone values on weekend days was higher than the mean for those on weekdays for all Coastal subregion stations considered, and for most (7 out of 9) of the Metropolitan subregion stations. However, the reverse was true for all of the Inland Valley subregion stations (as well as the one Mountain station), and for 2 out of 3 stations in both the San Gabriel Valley subregion and the Inland subregion.

For the period 1990-93, the means of the peak concentrations on the weekend days were higher than those on the weekdays for all stations in all subregions, with the exception of two stations in the far east end of the SoCAB: Crestline, and Banning (where the weekday means were only very slightly higher than those for weekend days). Comparing the magnitudes of the differences between the two four-year periods, we found a significant decrease in the degree to which the mean of the peak daily ozone values on weekend days exceeded that on weekdays in the Coastal subregion, while the reverse was true for the farther-inland subregions.

6.7 Examination of Individual Days with Highest Hourly-Average Ozone Concentrations for Each Year in the Period 1986-93

In Table 6-9 we present a listing of the 10 days with the highest hourly-average ozone values for each of the 8 smog seasons during the period 1986-93. (The number of days listed exceeds 10 for some of the years as all days tied at the 10th ranked value are included.) Here again, the decrease in highest ozone values through the eight-year period is evident.

Table 6-8. Weekday/weekend day differences in ozone concentrations at stations grouped by subregion in the SoCAB for 1986-89 and 1990-93. Ozone concentrations in pphm.

Subregion/Station	Period 1	Period 2
Coastal		
West L.A.	1.6	0.3
Hawthorne	3.5	1.0
Long Beach	2.5	2.1
Los Alamitos	1.0	0.3
Metropolitan		
Anaheim	0.7	3.6
La Habra	0.9	2.7
El Toro	-0.4	1.4
Burbank	1.1	4.3
Reseda	-0.9	0.3
Whittier	2.1	1.5
Lynwood	4.0	2.0
Pico Rivera	1.6	3.3
Central L.A.	0.5	2.9
San Gabriel Valley		
Azusa	-0.3	3.9
Pasadena	-0.6	3.0
Glendora	0.2	2.4
Inland		
Norco	-0.2	1.3
Upland	-2.1	1.3
Pomona	0.5	1.5
Inland Valley		
Hemet	-1.6	1.5
Riverside	-0.5	1.2
Perris	-0.6	1.3
Banning	-2.7	-0.1
Fontana	-1.3	0.7
San Bernardino	-2.0	1.9
Mountain		
Lake Gregory/Crestline	-1.5	-0.9

Period 1 = For 1986-89, the mean of the 10 highest daily maximum hourly average ozone concentrations occurring on either a Saturday or a Sunday minus the mean of those concentrations occurring on either a Tuesday or a Wednesday.

Period 2 = For 1990-93, the mean of the 10 highest daily maximum hourly average ozone concentrations occurring on either a Saturday or a Sunday minus the mean of those concentrations occurring on either a Tuesday or a Wednesday.

Table 6-9. The highest ozone concentrations in the SoCAB for each year in the period 1986-93. Ozone concentrations reported in pphm. Redlands data mission for Sept. 26 1986 to Oct. 31 1986. San Bernardino data missing for May 1986. Data completeness is 89+% for all other years and stations.

Station	Year	Month	Day	O_3 Max.	Hour of O_3 Max.	Day of Week	CART Node
Glendora	86	6	27	35	13	Fri	10
Glendora	86	6	26	34	14	Thu	8
Glendora	86	9	6	34	14	Sat	10
San Bernardino	86	9	4	30	15-16	Thu	10
Glendora	86	9	5	30	13	Fri	9
Burbank/Glendora	86	5	25	28	12/13	Sun	10
Glendora	86	8	8	28	14	Fri	6
Glendora	86	8	9	28	14	Sat	8
Upland	86	8	26	27	14	Tue	8
San Bernardino	86	6	24	27	15	Tue	8
Glendora	86	5	24	27	14	Sat	6
Glendora	86	7	19	27	13	Sat	6
Glendora	86	8	10	27	14	Sun	8
Glendora	86	8	11	27	13	Mon	10
Glendora	86	8	22	27	13	Fri	10
Glendora	87	9	1	32	13	Tue	10
Glendora	87	10	2	32	14	Fri	10
Azusa/Glendora	87	7	31	30	14/14-15	Fri	6
Glendora	87	9	30	30	13	Wed	10
Riverside	87	9	28	29	14	Mon	8
Glendora	87	8	28	29	14	Fri	10
West L.A.	87	10	3	28	13	Sat	10
Glendora	87	9	20	28	14	Sun	10
Riverside	87	8	1	27	13	Sat	10
Riverside	87	9	7	27	16	Mon	8
Riverside	87	9	29	27	14	Tue	8
Glendora	87	7	29	27	14	Wed	8
Glendora	87	7	30	27	14	Thu	6
Glendora	87	9	2	27	15	Wed	10
Glendora	87	9	19	27	14	Sat	6
Upland	88	9	2	35	14	Fri	10
Glendora	88	7	16	33	14	Sat	10
Glendora	88	7	17	31	13	Sun	10
Pico Riv./Glen.	88	9	3	30	12/13	Sat	9
Crestline	88	5	12	29	15	Thu	9
Glendora	88	8	25	29	13	Thu	10
Redlands	88	6	2	28	15	Thu	8
Azusa/Pasadena	88	5	11	28	13/12	Wed	6
Glendora	88	7	15	28	14	Fri	8
Az./Pasa./Glen.	88	7	20	27	15/14/15	Wed	8

Table 6-9. The highest ozone concentrations in the SoCAB for each year in the period 1986-93 (continued).

Station	Year	Month	Day	O_3 Max.	Hour of O_3 Max.	Day of Week	CART Node
Glendora	89	7	19	34	15	Wed	10
Glendora	89	6	14	33	14	Wed	10
Azusa	89	7	20	30	13	Thu	10
Glendora	89	9	13	29	14	Wed	8
Glendora	89	9	23	29	15	Sat	8
Glendora	89	7	28	28	14	Fri	8
Riverside	89	7	4	27	15	Tue	9
Upland/Glendora	89	7	18	27	15/14	Tue	7
Crestline	89	7	6	27	15-16	Thu	-1
Glendora	89	6	13	27	13	Tue	8
Glendora	89	7	3	27	14	Mon	10
Glendora	89	9	2	27	15	Sat	8
Crestline	90	6	25	33	16	Mon	10
Crestline	90	9	11	30	17	Tue	10
Riverside	90	6	26	29	14	Tue	10
Cres./Font./Glen.	90	6	4	27	16/14/13	Mon	10
Glendora	90	9	8	27	14	Sat	16
Fontana	90	7	19	26	16	Thu	10
Riverside	90	6	2	25	15	Sat	8
Riverside/Glen.	·90	6	3	25	15/14	Sun	10
Crestline	90	8	9	25	16	Thu	8
Glendora	90	9	9	25	15	Sun	10
Glendora	91	8	9	32	14	Fri	10
Glendora	91	8	8	31	14	Thu	8
Glendora	91	8	23	31	13	Fri	10
Crestline	91	7	2	27	15-16	Tue	10
Glendora	91	8	31	27	14	Sat	6
Glendora	91	7	13	26	14	Sat	6
An./Az./P.R./Glen.	91	10	19	25	14/14/13/14-15	Sat	10
Crestline	91	7	1	25	16	Mon	9
Crestline	91	7	29	25	16	Mon	9
Riverside	91	9	17	24	15	Tue	10
Newhall	91	7	3	24	15	Wed	9
Newhall	91	7	4	24	15	Thu	9
Glendora	91	8	22	24	14	Thu	6
Glendora	91	9	1	24	15	Sun	6
Glendora	91	10	6	24	15	Sun	8
Glendora	92	7	18	29	13	Sat	10
Glendora	92	8	1	28	14	Sat	10
Glendora	92	7	31	26	13	Fri	8
Glendora	92	8	17	26	15	Mon	10
Glendora	92	8	19	26	13	Wed	10
Fontana	92	8	12	25	14	Wed	10

Table 6-9. The highest ozone concentrations in the SoCAB for each year in the period 1986-93 (continued).

Station	Year	Month	Day	O_3 Max.	Hour of O_3 Max.	Day of Week	CART Node
Fontana/Glendora	92	8	15	25	15/14	Sat	10
Glendora	92	9	21	25	14	Mon	8
Upland	92	8	2	24	14	Sun	10
Crestline	92	8	10	24	16-17	Mon	10
Pomona	92	8	13	24	13	Thu	10
Glendora	92	9	20	24	15	Sun	6
Glendora	93	9	9	28	13	Thu	10
Glendora	93	6	15	25	14	Tue	6
Glendora	93	9	10	25	13	Fri	10
Crestline	93	8	5	24	15	Thu	6
Azusa/Glendora	93	8	1	24	13/13-14	Sun	10
Glendora	93	6	26	24	14	Sat	10
Azusa	93	7	31	23	13	Sat	10
Glendora	93	6	14	23	14-15	Mon	6
Upland	93	6	25	22	15-16	Fri	9
Crestline	93	8	4	22	15	Wed	8
Redlands	93	8	6	22	12	Fri	9
Pasadena	93	10	2	22	13	Sat	9
Newhall	93	9	11	22	13	Sat	9
Glendora	93	6	18	22	13	Fri	8
Glendora	93	6	19	22	13	Sat	8
Glendora	93	8	22	22	14	Sun	6

Number of Occurrences:

Day		Node	
Mon:	12	1	0
Tue:	12	2	0
Wed:	12	3	0
Thu:	16	4	0
Fri:	17	5	0
Sat:	24	6	17
Sun:	12	7	1
		8	26
		9	12
		10	48

O_3 Max. = daily maximum hourly average ozone concentration in pphm.

Hour of O_3 Max. = hour of the day (in PST) on which the daily maximum hourly average ozor concentration (in pphm) occurred.

Node = Node in Horie's CART (Horie 1987).

For each day, the peak ozone value, the location(s), date and time(s) of occurrence, day of the week, and CART node (see Chapter 5) are listed. More of the peak ozone values were found to occur at Glendora than at all other locations combined. During just the second four-year period, a not insignificant number of these peak values also occurred at Crestline.

Summaries of the distributions by day of the week and CART node are provided at the end of Table 6-9. The distribution by day-of-the-week shows these highest ozone values occurred significantly more often on Saturdays than on Sundays, Mondays, Tuesdays, or Wednesdays. The CART node summary reveals that, although more of these peak ozone values occurred on days meteorologically classified as node 10 in the CART scheme, even this node captured only 46% of these occurrences. Thus the CART scheme, at least in the form developed by Horie (1987) for his data base, did not appear to yield any one particular set of meteorological conditions associated with the occurrence of the highest ozone values in the SoCAB.

6.8 NO_2/NO_x Trends and Weekday/Weekend Differences in Ambient NO_2 and NO_x Concentrations, and NO_2/NO_x Ratios

6.8.1 Previous Studies

As noted elsewhere, earlier studies have shown significant weekday/weekend (WD/WE) differences in ozone and ozone precursors (NO_x and ROG) in the SoCAB (Horie 1988; Hoggan *et al.*, 1989). Horie (1988) analyzed the early morning 5-8 am PST NO_2 and NO_x data for the southern California region and found significant differences in NO_2 and NO_x concentrations, and NO_2/NO_x ratios between the period 1975-77 and the period 1984-86.

The South Coast Air Quality Management District has estimated that during the period 1976-82 there was a 30% reduction in ROG emissions and a 15% reduction in NO_x emissions in the SoCAB (SCAQMD 1983). From his analysis of 5-8 am PST ambient air concentration, Horie (1988) found a 10-15% decrease in NO_2, a 20-30% decrease in NO_x, and a 10-30% increase in the NO_2/NO_x ratio for the stations in the Coastal subregion he employed (Costa Mesa, Lennox, Long Beach). For the stations he used in the

Metropolitan subregion (Central Los Angeles, Anaheim, La Habra), Horie found a 0-5% decrease in NO_2, a 10-20% decrease in NO_x, and a 5-15% increase in their ratio between the two periods he investigated.

Horie (1988) also found significantly lower Saturday and Sunday levels of NO_2 and NO_x in both the Coastal and Metropolitan subregions for the time periods 1975-77 and 1984-86. The morning levels of NO_2 were found to be 10-20% lower and the morning levels of NO_x were found to be 30-40% lower on weekend-days than on weekdays. However, the NO_2/NO_x ratio was found to be higher by 20-40% on weekend-days as compared to weekdays.

Our initial goal was to extend the work of Horie (1988) to the eight-year period being investigated in the present study. Our first objective was to determine whether significant changes in primary pollutant concentrations occurred between the periods covered by Horie's study and the 1986-93 period of the present study. Inherent in both Horie's analysis and ours is the assumption that early morning ambient air NO_x concentration data for the west side of the SoCAB can be taken to reflect primary emissions of NO_x from mobile and stationary sources. Conditions which are consistent with this assumption for the 5-8 am PST (6-9 am PDT) period are very low wind speeds, relatively low solar insolation (between sunrise and 8 am), and a low-level inversion.

For comparison with Horie's data, the WD/WE differences in levels of NO_2, NO_x and their ratio in the Coastal and Metropolitan subregions were examined, and to minimize the influence of year-to-year meteorological variations, four-year averages for 1986-89 were compared to the four-year averages for 1990-93. Again to facilitate comparison with Horie (1988), the four-year averages were computed for Saturdays, Sundays, and Mondays, and for Wednesdays and Thursdays which were combined together as "typical" weekdays. Horie (1988) justified these choices by suggesting that weekend day emissions would differ from those on weekdays because, for example, many "stationary emission sources are not in operation on Sundays." Similarly, the morning commuter traffic that significantly contributes to high NO_x and VOC emissions on weekdays is not as prevalent on Saturdays and is even lower on Sundays (Zeldin *et al.* 1989). In addition, Horie and Zeldin *et al.* (1989) distinguished Monday ambient concentrations of NO_x from those of the other weekdays in terms of reduced carryover of NO_x emissions from weekend-days (Zeldin *et al.* 1989).

6.8.2 Calculation of Mean Morning NO_2 and NO_x Concentrations and NO_2/NO_x Ratios

The mean NO_2 and NO_x ambient concentrations for the 5-8 am PST period were calculated for each day in the smog season for three stations in the Coastal subregion (as defined by Horie 1988) for the eight-year period of this study. The daily mean ratio was obtained by dividing the daily mean NO_2 by the daily mean NO_x and averaging these means for all three stations in the Coastal subregion. The same procedure was used to calculate the Metropolitan daily mean NO_2, NO_x, and NO_2/NO_x ratio. In the event the daily mean NO_2 and NO_x ambient concentrations for a given station in a subregion were both 0 pphm, the daily ratio was equated to zero and not included in calculating the daily mean ratio for that subregion. Less than 5% of the NO_2 and NO_x daily means for any given station were both observed to be zero.

It should be noted that the mean of the NO_2/NO_x ratios calculated from averaging the individual daily ratios will not necessarily be the same as the ratio calculated from the mean NO_2 and mean NO_x values. This explains the differences observed in Tables 6-10 and 6-11 between the reported values of the NO_2/NO_x ratio and the values that would be obtained by dividing the reported NO_2 means by the reported NO_x means.

Table 6-10 shows the mean morning concentrations of NO_2 and NO_x, and the NO_2/NO_x ratios for the Coastal and Metropolitan subregions for 1986-89 and Table 6-11 shows the mean morning concentrations of NO_2 and NO_x, and the NO_2/NO_x ratios for 1990-93. The following differences were observed between weekdays, weekend days and Mondays for the two four-year periods under study here.

WD vs. Saturday: Taking the means of the NO_2 and NO_x concentrations and the NO_2/NO_x ratios for the combined Coastal and Metropolitan subregions for the period 1986-89, Saturdays had 18% lower NO_2 levels, 32% lower NO_x levels, and 17% higher NO_2/NO_x ratios than the weekday average. Similar results were found for the period 1990-93.

Table 6-10. Mean morning (5-8 am PST) concentrations of NO_2, NO_x (in pphm), and NO_2/NO_x ratios on selected weekdays (Wednesdays and Thursdays), Saturdays, Sundays, and Mondays during May-October 1986-89.

	WD	Saturday	Sunday	Monday
Coastal				
Stat. Days	209	105	105	106
NO_2	3.10	2.56	2.35	2.93
NO_x	8.05	5.71	4.95	7.65
Ratio	0.39	0.44	0.48	0.39
Metropolitan				
Stat. Days	209	105	105	106
NO_2	3.54	2.90	2.58	3.38
NO_x	8.81	5.75	4.61	8.72
Ratio	0.39	0.47	0.52	0.39

Table 6-11. Mean morning (5-8 am PST) concentrations of NO_2, NO_x (in pphm), and NO_2/NO_x ratios on selected weekdays (Wednesdays and Thursdays), Saturdays, Sundays, and Mondays during May-October 1990-93.

	WD	Saturday	Sunday	Monday
Coastal				
Stat. Days	211	106	105	104
NO_2	2.65	2.18	1.92	2.37
NO_x	7.77	5.23	3.75	6.27
Ratio	0.37	0.43	0.48	0.41
Metropolitan				
Stat. Days	211	106	105	104
NO_2	3.06	2.63	2.24	2.81
NO_x	8.56	5.86	4.04	7.07
Ratio	0.38	0.46	0.53	0.43

WD vs. Sunday: Again, combining the data for the Coastal and Metropolitan subregions, for the period 1986-89, Sunday had 26% lower NO_2 levels, 43% lower NO_x levels, and 28% higher NO_2/NO_x ratios than the weekday average. Corresponding values for the period 1990-93 were 27%, 52%, and 36% respectively.

WD vs. Monday: Combining the data for the Coastal and Metropolitan subregions, for the period 1986-89, NO_2 levels were 5% lower on Mondays than on weekdays, NO_x levels were 3% lower on Mondays, and NO_2/NO_x ratios were the same on weekdays and Mondays. For the period 1990-93, NO_2 levels were 9% lower on Mondays than on weekdays, NO_x levels were 18% lower on Mondays, and NO_2/NO_x ratios levels were 12% higher on Mondays as compared to the average weekday.

Thus, during the 1986-93 period, average morning NO_2 and NO_x ambient concentrations on weekend days were approximately 20-25% and 30-50% lower, respectively, than on weekdays (*i.e.*, Wednesdays/Thursdays) in the Coastal/Metropolitan subregions.

In general, these early morning ambient air concentration data suggest that for all smog season days taken together a modest decrease in emissions of NO_x occurred in the Coastal/Metropolitan subregions between the two four-year periods under study here. Specifically, combining the NO_x data for the two subregions, weekdays (as represented by Wednesday/Thursday) and Saturdays showed only a 3% decrease in NO_x concentrations between 1986-89 and 1990-93, while Sunday and Monday showed an 18% decrease in NO_x concentrations for the combined subregions. The change in NO_2 concentrations was more uniform across the days of the week, with decreases of 14% for WD, 12% for Saturday, 16% for Sunday and 18% for Monday.

This result for all smog season days for the Coastal/Metropolitan subregions is in marked contrast to the case for the days corresponding to the top ten ozone episodes for which a much larger decrease in NO_x occurred between the two four-year periods for the Coastal/Metropolitan subregions (see below and Figure 6-35).

6.8.3 Statistical Significance of Observed Differences

The weekdays vs. weekend days and weekdays vs. Monday differences were analyzed using t-test statistics; Tables 6-12 and 6-13 show the results. Statistically significant differences were observed between weekdays and Saturdays, and weekdays and Sundays, for NO_2, NO_x, and their ratio for both four-year periods. The differences between weekdays and Mondays were not statistically significant for NO_2, NO_x, and their ratio for 1986-89. In comparing weekdays with Mondays for the period 1990-93, statistically significant differences were found for NO_2 concentrations for the Coastal subregion and for NO_2/NO_x ratios for both Coastal and Metropolitan subregions.

6.8.4 NO_2 and NO_x Trends for Ten Highest Ozone Days

Tables 6-14 and 6-15 provide data for the mean 5-8 am (PST) NO_2 and NO_x ambient concentrations, respectively, for eighteen air monitoring stations for the ten highest ozone days in the two periods 1986-89 and 1990-93, as well as the differences in these means (as shown earlier in Figure 6-35). As can be seen from Figure 6-35, NO_x morning ambient concentrations for the ten highest days decreased markedly in the Coastal/Metropolitan subregion stations examined over this eight-year period, while there were generally modest decreases in the San Gabriel Valley and Inland Valley subregions, and in several cases (Pomona, Anaheim, Riverside and La Habra) modest increases in NO_x. Decreases in morning ambient NO_2 concentrations were more modest and more uniform across the Basin than was the case for NO_x. It is interesting that, as noted above, the western edge of the Basin was the site of both the largest decrease in morning ambient concentrations (and hence presumably emissions) of NO_x, and the largest percent decrease in ozone (see Figure 6-34) for the top ten ozone days at each station.

6.8.5 NO_2 Concentrations for 28 Highest and Middle Ozone Days

In connection with our earlier comparisons (see Chapter 5) between 28 highest ozone days vs. 28 "middle" ozone days for the period 1990-93 (for the stations at Glendora, Crestline, Fontana and Riverside), we have also examined the corresponding early morning NO_2 ambient concentrations for these specific collections of days for

Table 6-12. t-Test for morning (5-8 am PST) concentrations of NO_2 and NO_x, and for NO_2/NO_x ratios for differences between weekdays and weekend-days and Mondays for (May-October) 1986-1989.

Variable/ Subregion	WD-Saturday t-statistic	WD-Sunday t-statistic	WD-Monday t-statistic
Coastal			
NO_2	4.64†	6.04†	1.41
NO_x	3.47†	4.71†	0.57
Ratio	-3.13†	-5.49†	0.00
Metropolitan			
NO_2	4.43†	6.51†	1.09
NO_x	4.62†	6.54†	0.12
Ratio	-5.01†	-8.36†	0.00

† Highly significant differences between two means ($p < 0.01$)

Table 6-13. t-Test for morning (5-8 am PST) concentrations of NO_2, NO_x, and NO_2/NO_x ratios for differences between weekdays and weekend-days and Mondays for (May-October) 1990-93.

Variable/ Subregion	WD-Saturday t-statistic	WD-Sunday t-statistic	WD-Monday t-statistic
Coastal			
NO_2	3.99†	6.27†	2.40†
NO_x	3.44†	5.75†	1.95§
Ratio	-3.68†	-6.90†	-2.44
Metropolitan			
NO_2	3.15†	5.95†	1.77§
NO_x	3.57†	6.25†	1.84§
Ratio	-4.28†	-8.56†	-2.66†

§ Significant differences between two means ($p < 0.05$)

† Highly significant differences between two means ($p < 0.01$)

Table 6-14. Average morning (5-8 am PST) NO_2 concentration (pphm) for top ten ozone days in the indicated periods.

Station	P1	P2	P2-P1
	Average Morning NO_2		
Anaheim	5.7	6.3	0.6
Hawthorne	6.1	5.3	-0.8
San Bernardino	6.6	5.0	-1.6
Upland	7.7	6.6	-1.1
La Habra	5.8	6.6	0.8
Riverside	5.9	7.2	1.3
Fontana	7.8	6.7	-1.1
Azusa	7.4	6.8	-0.6
Burbank	6.7	5.8	-0.9
Long Beach	5.6	3.7	-1.9
Reseda	5.9	5.0	-0.9
Pomona	8.5	8.4	-0.1
Whittier	6.5	4.8	-1.7
Lynwood	7.3	5.0	-2.3
Pico Rivera	6.5	5.5	-1.0
Central LA	8.4	6.8	-1.6
Pasadena	6.6	5.1	-1.5
West LA	6.6	5.8	-0.8
Average	6.8	5.9	-0.9

P1 = Average morning (5-8 am PST) NO_2 concentrations for the top ten ozone days in 1986-89.

P2 = Average morning (5-8 am PST) NO_2 concentrations for the top ten ozone days in 1990-93.

Table 6-15. Average morning (5-8 am PST) NO_x concentration (pphm) for the top ten ozone days in the indicated periods.

	Average Morning NOx		
Station	P1	P2	P2-P1
Anaheim	12.5	16.0	3.5
Hawthorne	26.5	13.4	-13.1
San Bernardino	10.7	7.4	-3.3
Upland	12.3	10.4	-1.9
La Habra	12.8	14.1	1.3
Riverside	15.1	17.0	1.9
Fontana	13.4	12.4	-1.0
Azusa	14.7	14.0	-0.7
Burbank	16.3	14.3	-2.0
Long Beach	14.1	7.3	-6.8
Reseda	11.1	8.3	-2.8
Pomona	19.6	19.8	0.2
Whittier	13.4	12.4	-1.0
Lynwood	26.4	11.5	-14.9
Pico Rivera	21.2	15.7	-5.5
Central LA	21.6	20.8	-0.8
Pasadena	13.2	10.7	-2.5
West LA	25.4	19.4	-6.0

P1 = Average morning (5-8 am PST) NO_x concentrations for the top ten ozone days in 1986-89.

P2 = Average morning (5-8 am PST) NO_x concentrations for the top ten ozone days in 1990-93.

twenty-one stations in the Basin.

In Table 6-16 are presented 5-8 am (PST) mean NO_2 ambient air concentrations for the 28 highest and 28 middle ozone days examined earlier, and their difference. From a comparison of the data in Tables 6-14 and 6-16, it can be seen that the magnitude of early morning NO_2 ambient concentrations generally correlated with the level of subsequent ozone on the same day. Specifically, for the 1990-93 period, the overall average morning NO_2 concentrations (for eighteen or twenty-one stations) was 5.9 pphm for the ten highest ozone days, 5.3 pphm for the 28 highest days and 3.7 pphm for the 28 middle days.

Table 6-16. Average morning (5-8 am PST) NO_2 concentrations (pphm) for 28 high and 28 middle ozone days.

Station	High-Ozone Days	Mid-Ozone Days	Difference[a]
Anaheim	4.7	3.2	1.5
El Toro	5.4	3.4	2.0
Costa Mesa	2.5	1.8	0.7
Riverside	6.5	4.0	2.5
Upland	6.3	4.7	1.7
Fontana	6.5	4.7	1.7
San Bernardino	5.2	3.9	1.3
Azusa	6.4	3.8	2.6
Burbank	6.3	4.2	2.1
Long Beach	3.9	2.9	1.1
Reseda	6.1	3.8	2.4
Pomona	8.2	5.1	3.1
Whittier	4.4	3.2	1.2
Lynwood	4.6	3.1	1.5
Pico Rivera	5.5	3.9	1.7
Central LA	6.5	4.1	2.5
Pasadena	5.4	3.9	1.5
Newhall	5.1	4.2	0.9
West LA	4.0	2.7	1.3
Hawthorne	4.1	3.1	1.1
Glendora	4.5	3.7	0.7
Average	5.3	3.7	1.6

[a] Including rounding.

6.9 Summary

Some of the findings of greatest interest from data presented in this chapter were as follows.

- As well documented earlier by the ARB, SCAQMD and others, substantial reductions in peak ozone concentrations occurred in all regions of the Basin and across all days of the week between 1986-89 and 1990-93, although the percentage reductions were greatest in the western and middle portions of the Basin. On average there were greater reductions on weekdays than on weekends and hence the differences in WD vs. WE daily ozone maxima increased in the 1990-93 period over the 1986-89 period.

- An examination of the worst ozone days, specifically the ten highest daily hourly-average ozone concentrations for each of the two four-year periods for each station for which data were available, showed the most pronounced percentage decrease in these highest ozone concentrations occurred in the western and middle portions of the Basin, corresponding generally to the area of maximum percentage decrease in early morning NO_x ambient concentrations for these same highest ozone days.

- The distribution by day-of-the-week of the ten (or more if there were ties) days with highest ozone concentrations in the Basin for each year in the period 1986-93, showed these episodes occurred significantly more often on Thursdays through Saturdays than on Sundays through Wednesdays.

- For the period 1990-93, the means of the peak ozone concentrations for the top ten days were higher on weekend days than on weekdays for all stations in all subregions (with the exceptions of Crestline and Banning). For the period 1986-89, this was true in general only for the Coastal subregion.

- On average, early morning ambient concentrations of NO_2 and NO_x during the eight-year period studied were lower by approximately 20-25% and 30-50%, respectively on weekend days than on typical weekdays in the Coastal/Metropolitan subregions.

7.0 EXPLORATORY STUDIES

The original specific objectives of this project included the following two topics of investigation characterized as exploratory. First, to evaluate further the meteorological representativeness of the August 1987 SCAQS episode, which has been and will be used for urban airshed modeling in support of VOC/NO_x control strategies and future air quality management plans; and second, to explore multiple linear regression relationships between meteorological parameters and ozone. In proposing these exploratory studies, we tacitly made two assumptions: that sufficient time and resources would remain after completing the primary objectives to enable the exploratory objectives to be reasonably addressed, and that the level of priority ascribed to these tasks at the beginning of the project would remain unchanged. Neither of these assumptions proved to be entirely valid, however. First, collecting, organizing, and documenting our database required significantly more effort than was originally anticipated; second, the time and resources allocated to this research effort were largely expended upon completion of the assemblage of the database and performance of the analyses requisite to addressing the specific primary objectives of the project; and third, we felt it important to pursue the NO_x/NO_2 correlations with daily maximum ozone, an aspect of the study which yielded results directly pertinent to the key issues of transport, residence time, and weekday-weekend differences.

Moreover, further additional analysis during the course of the project led to the realization that both exploratory objectives were, in various ways, problematic. The first of these objectives concerned the meteorological representativeness for the August 1987 SCAQS episode. The two primary problems here were inadequate availability of meteorological data (which, with much effort, was largely rectified), and lack of an effective and suitably robust means of determining meteorological similarity. (In fact, a significant objective of the proposed second phase to the present project is the determination of a technique for assessing meteorological similarity with respect to ozone formation in the SoCAB.)

The second exploratory objective concerned the exploration of multiple linear relationships between meteorological parameters and ozone. Here, too, further thought revealed such a determination would require protracted sophisticated statistical analysis more appropriate as a primary objective of a future research project than as an exploratory objective here. This became especially evident when it was realized that meteorology-ozone relationships would likely be different for each subregion of the SoCAB.

Nonetheless, certain progress was made on both of these exploratory topics and these results are reported here.

7.1 Meteorological Representativeness of the August 1987 SCAQS Episode

Significant examination of the August 1987 SCAQS episode has previously been performed and reported by other investigators. In the present study, we took the approach of comparing the meteorological characteristics of the 28 August 1987 key day of the episode with those characterizing our groups of high and middle ozone days in general (as described in Chapter 5), with the *caveat* these groups of ozone days were defined with respect to the period 1990-1993.

7.1.1 Resultant Surface Winds

The 1-hour resultant winds from 0700 to 1800 PDT 28 August 1987 were compared with the vector-average 1-hour resultant winds for the respective sets of high ozone days and middle ozone days. It should be noted the magnitude of the 1-hour resultant winds for a particular time of a particular day will typically be larger than that of the vector-average for that time for a large set of days (as a consequence of the vector-averaging process of the latter). Thus, for example, it is neither surprising nor necessarily indicative of inconsistency that there were several reports of 2 and 3 knot winds within the SoCAB for 0800-0900 PDT on 28 August (not shown), while this is not the case for this hour for either the high or middle ozone days.

The surface wind field for 0900-1000 PDT on 28 August (Figure 7-1) was quite similar to the vector-average winds for this same hour for the high ozone days (Figure 5-1). However, as wind speeds were, in both cases, very light, and as there was little

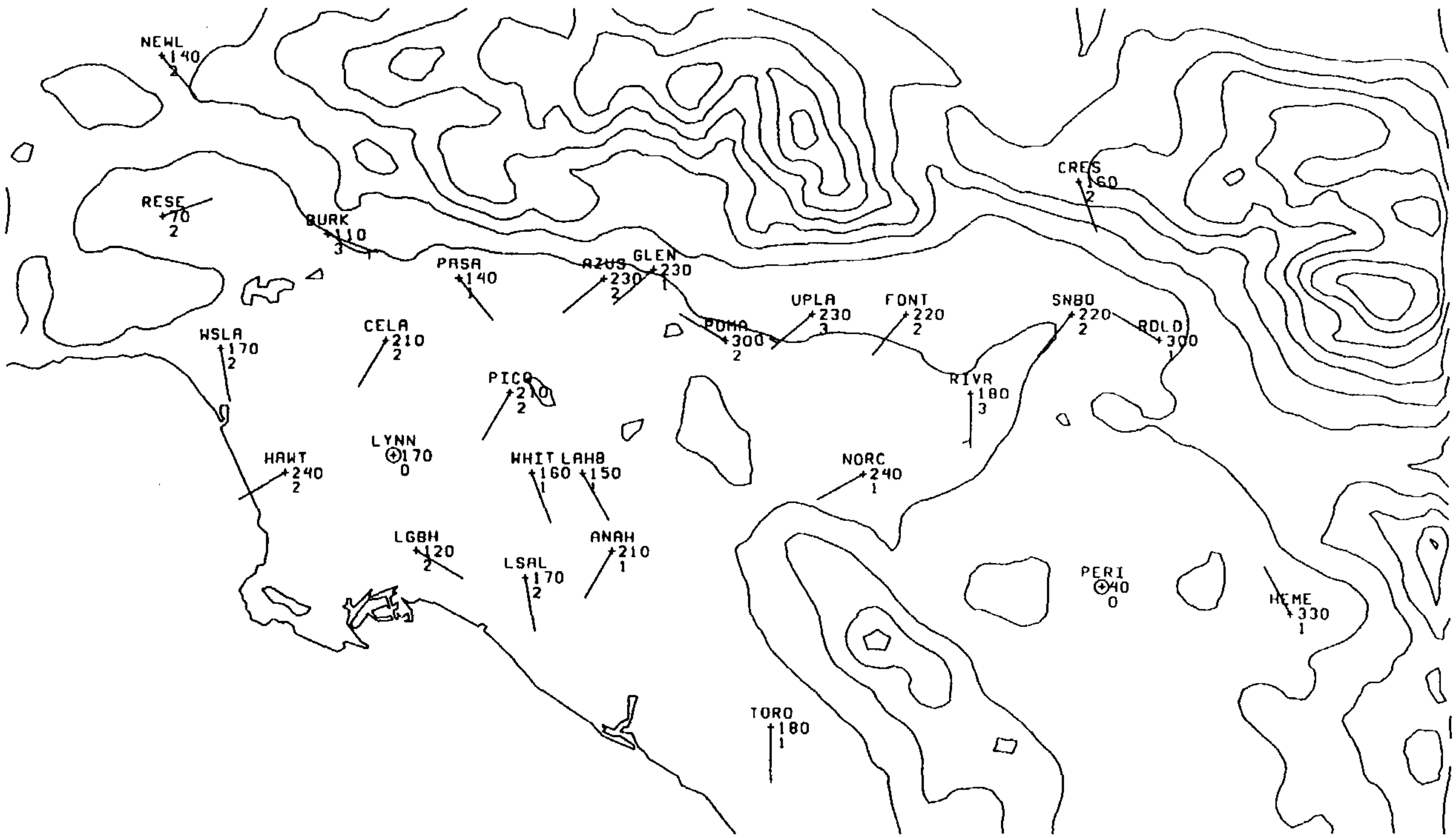

Figure 7-1. 0900-1000 PDT hourly-average surface winds for 28 August 1987. Wind direction (degrees) and wind speed (knots) are indicated.

apparent difference between the vector-average winds for high ozone days and the corresponding winds for the middle ozone days (Figure 5-2), little can be concluded from this. Except for the greater wind speeds and the more pervasive presence throughout the SoCAB of generally westerly-southwesterly surface flow, a very similar situation existed for the hour 1200-1300 PDT (Figure 7-2). As discussed in Section 5.1.1 these resultant winds were quite similar for both the high ozone days and the middle ozone days. The only slight difference noted was in the slightly more southerly orientation to the flow for middle ozone days in the southwestern part of the SoCAB (with Long Beach, Lynwood, and Costa Mesa mentioned in particular). Even here, nothing in particular can be concluded as the Long Beach wind bears greater similarity to the Long Beach winds for middle ozone days, while the reverse is true for Lynwood, and no reports were sent from the location of Costa Mesa. As the high degree of similarity of the wind fields for the high and middle ozone days continued through the remainder of the afternoon hours, little can be concluded at these times, too. One additional wind field analysis for 28 August is presented in Figure 7-3 for the hour 1600-1700 PDT; this can be compared with those given in Figures 5-7 and 5-8 for the high and middle ozone days, respectively.

7.1.2 Time of Peak Ozone Occurrence

To further examine the similarity in meteorological conditions between the 28 August 1987 SCAQS episode and those characterizing the 28 high ozone days from 1990-1993, we compared the time of peak ozone occurrence at each SoCAB station on 28 August (Figure 7-4) with the average for the 19 out of 28 high ozone days on which the peak ozone value similarly occurred at Glendora (Figure 5-11). The comparison was limited somewhat by the one-hour resolution of the ozone data; nonetheless broad similarity was evident when these two analyses were compared. With the exception of 5 stations, all in the metropolitan subregion of the Basin, the difference in times between 28 August and the mean for the 19 Glendora days was 42 minutes or less. At La Habra, Whittier, Long Beach, Downtown L.A., and Burbank, however, differences in time range from 48 to 90 minutes. This may, at least in part, be a consequence of changes in amounts and distributions of emissions between 1987 and 1990-93.

Figure 7-2. 1200-1300 PDT hourly-average surface winds for 28 August 1987. Wind direction (degrees) and wind speed (knots) are indicated.

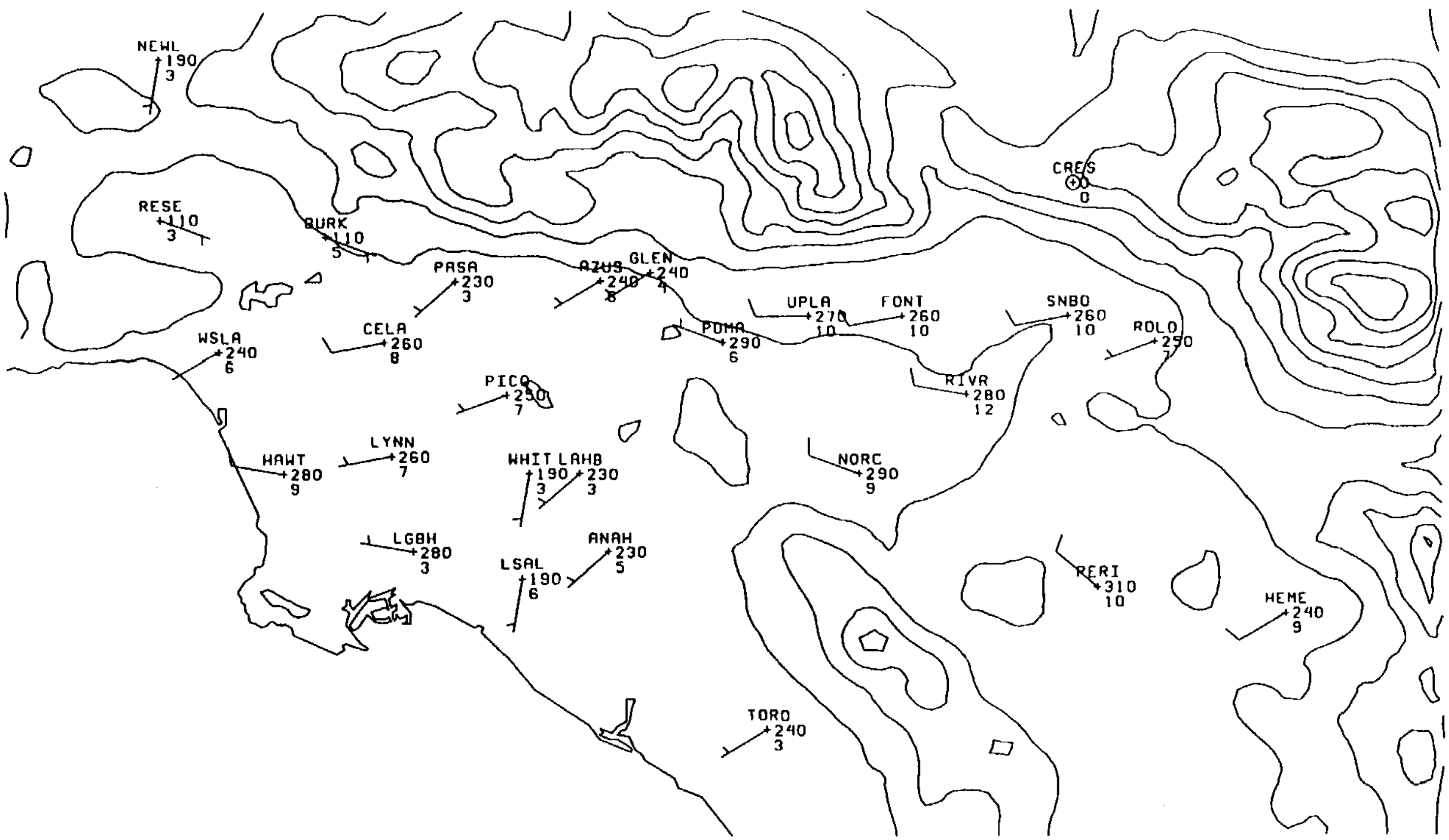

Figure 7-3. 1600-1700 PDT hourly-average surface winds for 28 August 1987. Wind direction (degrees) and wind speed (knots) are indicated.

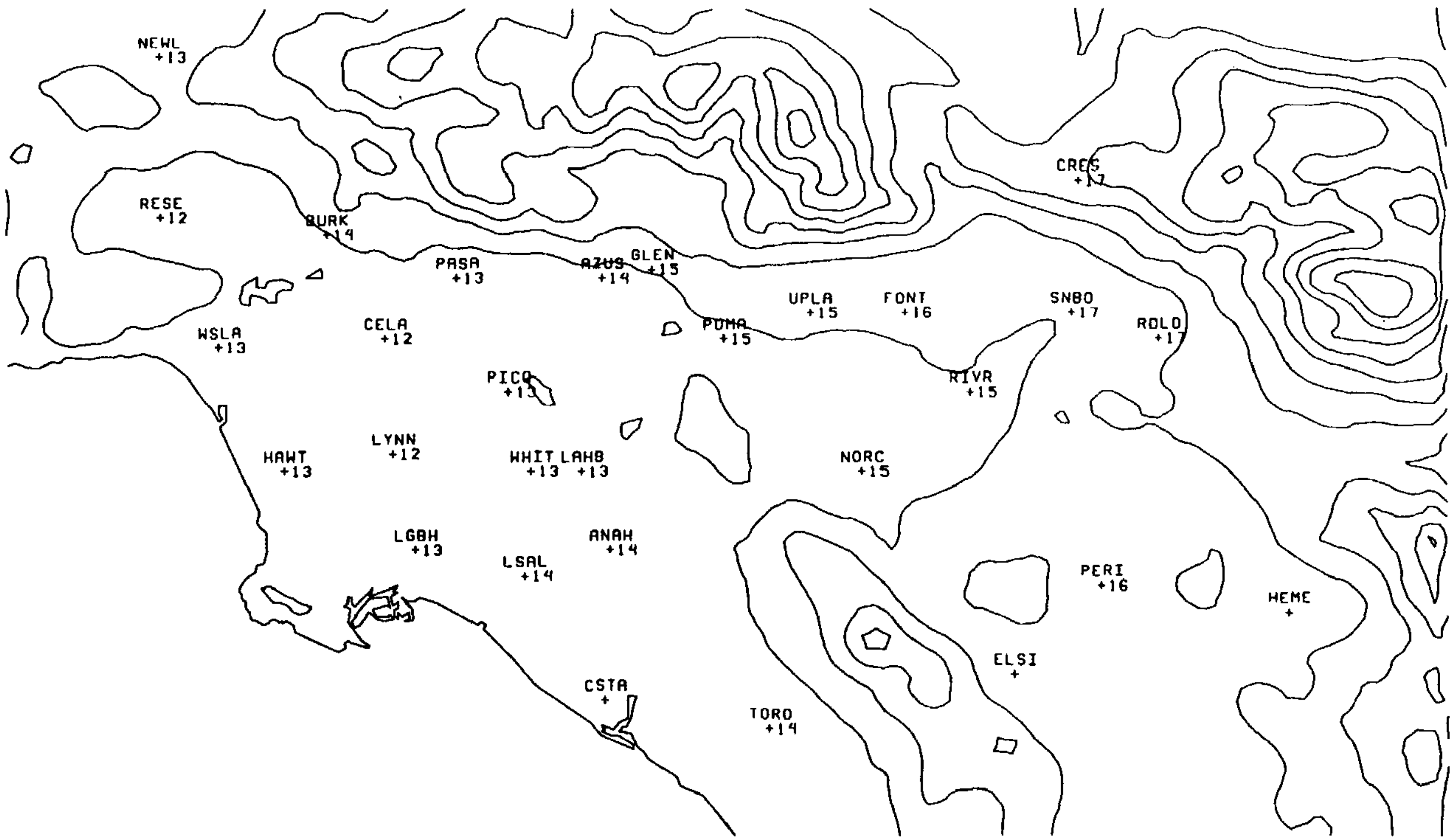

Figure 7-4. Initial times of occurrence (PDT) of peak ozone for 28 August 1987. Plotted times represent beginning of first hour of occurrence.

7.1.3 Surface Temperatures

The maximum hourly-average surface air temperatures for all stations within the SoCAB for which such data were available for 28 August 1987 are plotted in Figure 7-5. Unfortunately, data were only available for 11 of the stations. Maximum temperatures varied from 73 °F at Hawthorne to 98 °F at Upland. Values were 4 °F to 9 °F cooler in the Coastal/Metropolitan subregions of the Basin on 28 August than for the average of the 28 high ozone days (Figure 5-18), while farther to the east, Azusa and Riverside were each 4 °F cooler and Upland was 2 °F warmer. High temperatures on 28 August in the western parts of the SoCAB thus seemed to bear greater similarity to those for the 28 middle ozone days (Figure 5-19), while temperatures farther to the east were closer to those characterizing the high ozone days.

7.1.4 850 mb Temperatures

As described in Section 5.2.1, the 850 mb temperatures at San Diego and Vandenberg AFB were averaged at each of the two daily observation times, in order to obtain an 850 mb temperature representative of the SoCAB. Thus the mean 850 mb temperature for 1200 GMT (0500 PDT) 28 August 1987 was 23.2 °C, while that for 0000 GMT 29 August (1700 PDT 28 August) was 23.5 °C. The latter value can be compared with the mean temperature of 25.0 °C and standard deviation of 1.8 °C for the 28 high ozone days, and the mean temperature of 19.5 °C and standard deviation of 1.9 °C for the 28 middle ozone days (see Section 5.2.1). The afternoon 850 mb temperature for 28 August, then, was lower than the average for the high ozone days, but within one standard deviation of the mean. When compared with the distributions of 850 mb temperatures for the 28 high and middle ozone days (Figure 5-22), it is clear that while the value for 28 August was towards the lower end of values for the high ozone days, it was above all of the values for the middle ozone days.

7.1.5 850 mb Winds

Consistent with the methodology described in Section 5.2.2 for the sets of 28 high and middle ozone days, winds at Vandenberg AFB and San Diego were considered

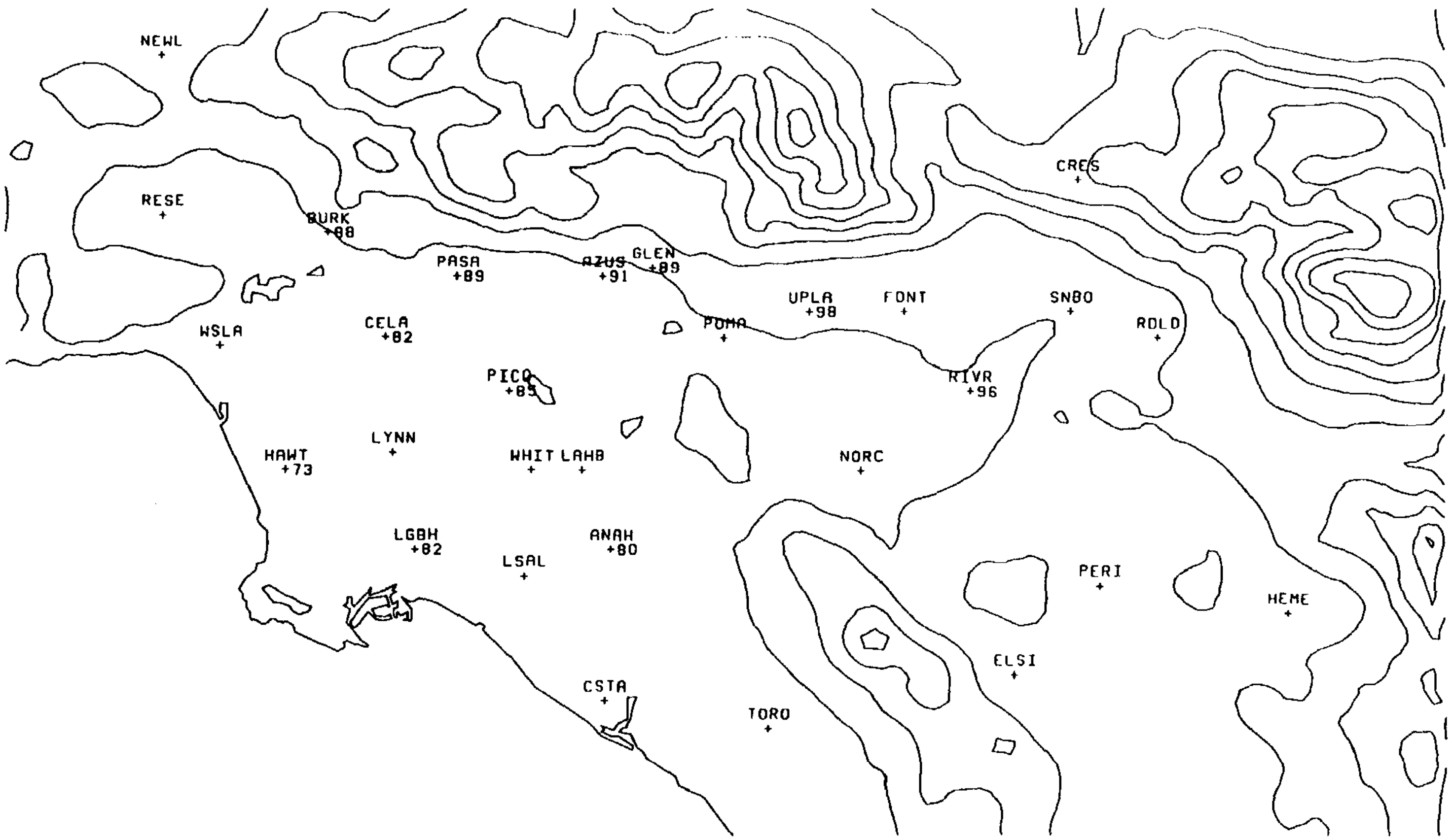

Figure 7-5. **Maximum hourly-average surface temperatures (°F) for 28 August 1987.**

individually rather than being averaged together as were the temperatures from these locations. At 0500 PDT 28 August, the 850 mb wind at Vandenberg AFB was from 095° at 2.9 knots while that at San Diego was from 160° at 13.0 knots. These were not particularly similar to the respective resultant wind speeds and directions for the high ozone days of 003° at 8.0 knots and 324° at 4.5 knots (from Table 5-2). Agreement was also poor in the afternoon (1700 PDT); at this time on 28 August 1987 the 850 mb wind at Vandenberg AFB was from 165° at 8.9 knots in contrast to the resultant wind for the high ozone days of 359° at 6.3 knots, while that at San Diego on 28 August was 130° at 4.1 knots in contrast to the resultant wind for the high ozone days of 301° at 3.5 knots. However, wind roses for these two stations for the high ozone days at 1700 PDT (Figure 5-23), contain a wide range of 850 mb wind directions, as do corresponding wind roses for the middle ozone days. Thus the 850 mb wind may not directly have a significant influence on the SoCAB peak ozone level.

7.1.6 Pattern Number

The pattern number assigned to 28 August 1987 was 4. As defined by Cassmassi (1987) (and schematically illustrated in Figure 5-24), the corresponding pattern is one of a high pressure ridge over California, with 500 mb heights approaching or exceeding 5880 m throughout the study area. This pattern was associated with all but three of the high ozone days, while the majority of the middle ozone days were associated with pattern number 3 (zonal flow or "building" high pressure ridge, characterized by a moderate pressure gradient and 500 mb heights somewhat higher to the southwest).

7.1.7 CART Scheme Classification

The CART node for 28 August 1987 was 10. This was the CART node associated with the highest SoCAB peak ozone levels for the each year during the period 1986-1993. For a day to be classified into this node, the following meteorological conditions must be met: morning 850 mb temperature greater than 17.1 °C; morning 900 mb temperature greater than 24.3 °C; and morning resultant wind direction at El Toro within the range west-southwesterly to northwesterly. A total of 15 days during the 1987 smog season were classified as node 10; the average SoCAB hourly-peak ozone level for these days was 24.8. This was significantly lower than the actual peak ozone value for 28 August of 29 pphm at Glendora (though no other station reported an ozone value higher than 24).

7.2 Multiple Linear Regression Relationships Between Meteorological Parameters and Ozone

As noted earlier in this Chapter, full consideration of the potential for developing multiple linear regression relationships would constitute an entire separate research project. Nonetheless, results of the present investigation do provide some potentially useful guidance.

Previous studies have examined the utility of various meteorological parameters in indicating some metric of the observed ozone level in the SoCAB. Perhaps the most robust single variable linear regression relationship is that which has been found with the 850 mb temperature (*e.g.*, Davidson et al. 1985). For each year from 1975 to 1990, for example, a best-fit linear regression relationship was determined between the 850 mb temperature from the morning radiosonde in the western and southwestern coastal portions of the Basin and a 6-station composite 1-hour average ozone maximum (Hoggan et al. 1991). Correlation coefficients varied from a minimum of 0.698 (in 1988) to a maximum of 0.850 (in 1980).

Results of the present study are consistent with the presence of a robust relationship between 850 mb temperature and SoCAB peak ozone level. In addition, it would appear there is a strong relationship between ozone concentration and surface maximum temperature. Little relationship, however, was seen between either the surface or 850 mb wind and the ozone concentration.

Interestingly, though, a very strong relationship was found between morning NO_2 concentrations in the San Gabriel Valley and Inland Valley subregions of the SoCAB and the Basin maximum ozone concentration. Since it would appear exceedingly unlikely that emissions change so substantially from day-to-day as to account for the range of NO_2 concentrations observed, this variation instead is likely reflecting differences in meteorological conditions -- and apparently these are meteorological conditions also relevant to the peak concentration of ozone observed later in the day.

Although further study will be needed to understand which meteorological parameters are most closely related to NO_2 concentration, there is no *a priori* reason to assume they necessarily include the 850 mb temperature. In fact, it would seem more likely the morning NO_2 concentration is related to the mixing depth, though unfortunately the data necessary to test this hypothesis are not at present available to us.

A reasonable starting point, then, for future efforts at developing multiple linear regression relationships for ozone would be to see how much of the variance is captured by use of the combination of morning 850 mb temperature and the morning NO_2 concentration.

8.0 SUMMARY AND CONCLUSIONS

The principal findings and conclusions of this study are summarized in brief below. See the corresponding report sections for detailed discussions. For completeness, we also present a discussion of the limitations to the present analyses.

8.1 Correlation of Ozone Concentrations with NO_2 and NO_x Ambient Concentrations

- Peak ozone concentrations in the SoCAB were generally better correlated with NO_2 concentrations than with NO_x concentrations.

- In general, the highest correlations between morning NO_2 and peak ozone concentrations occurred on weekend-days and Fridays.

- High intra-subregion correlations between morning NO_2 and peak ozone were observed throughout the Basin, particularly in the San Gabriel Valley and Inland Valley subregions.

- Correlations were weak between evening NO_2 or NO_x and the next day's Basin peak ozone during the Summer smog season during the 1986-93 period.

- Significant differences in these correlations were observed between the 1986-89 and 1990-93 periods, suggesting continuing changes in the spatial distribution of emissions in the Basin over this period, or the influence of different summer season meteorological patterns.

8.2 Meteorological Analyses

- Little difference in surface wind field was evident between high ozone days and average ozone days.

- Differences in 850 mb winds between high ozone days and average ozone days were also small.

- Maximum surface air temperatures and both early morning and late afternoon 850 mb temperatures were significantly higher on high ozone days than on average ozone days.

- Application of the CART scheme to each of the 8 years of the study showed the highest Basin-maximum ozone concentration was associated with node 10, which is characterized by very warm temperatures at 850 mb and 900 mb, as well as morning onshore flow at El Toro.

- Basin-maximum ozone values associated with CART node 10 were significantly lower in the latter four years than in the first four years covered by this study, and were lower for all years of the present study than the 1983-85 average for this node of 28.9 reported by Horie. Thus, under similar meteorological conditions conducive to ozone formation, peak ozone values have decreased.

8.3 Ozone Trends and Weekday/Weekend Effects

- As well documented earlier by the ARB, SCAQMD and others, substantial reductions in peak ozone concentrations occurred in all regions of the Basin and across all days of the week between 1986-89 and 1990-93, although the percentage reductions were greatest in the western and middle portions of the Basin. On average there were greater reductions on weekdays than on weekends and hence the differences in WD vs. WE daily ozone maxima increased in the 1990-93 period over the 1986-89 period.

- An examination of the worst ozone days, specifically the ten highest daily hourly-average ozone concentrations for each of the two four-year periods for each station for which data were available, showed the most pronounced percentage decrease in these highest ozone concentrations occurred in the western or middle portion of the Basin, corresponding generally to the area of maximum percentage decrease in early morning NO_x ambient concentrations for these same highest ozone days.

- The distribution by day-of-the-week of the ten highest ozone concentrations in the Basin for each year for each station in the period 1986-93, showed these episodes occurred significantly more often on Thursdays through Saturdays than on Sundays through Wednesdays.

- Similarly, for the period 1990-93, the means of the peak ozone concentrations for the top ten days were higher on weekend days than on weekdays for all stations in all subregions (with the exceptions of Crestline and Banning). For the period 1986-89, this was true in general only for the Coastal subregion.

- On average, early morning ambient concentrations of NO_2 and NO_x during the eight year period studied were lower by approximately 20-25% and 30-50%, respectively, on weekend days than on typical weekdays in the Coastal/Metropolitan subregions.

8.4 Limitations to the Present Analysis

For most of the smog season days during the period of the study (1986-93), little or no information was available concerning either the ozone concentration or the wind field at above-surface levels over the SoCAB. In particular, no location-specific, daily sounding data from anywhere within the SoCAB were included in the data sets transmitted to us. In addition, surface wind field data made available to us only included 1-hour resultant winds from the various SCAQMD telemetered stations. Instantaneous and 5-minute average wind data were not included; neither were data from the various FAA stations within the SoCAB for the majority of the years of the present study.

Moreover, the ready usefulness of both the meteorological and air quality data sets we did receive was compromised by the apparent absence of systematic post-acquisition quality control of the data -- most of the data sets contained some missing or erroneous data. We were thus required to spend substantial time and effort on developing and implementing procedures to remove erroneous information from the various data files. In addition, we are of necessity left uncertain as to whether we have in fact managed to remove just the incorrect information and retain solely the correct data. Most error checking involves either comparison to a known range of reasonable values of the particular type of data, or "buddy checks" in which the datum in question is compared with temporally and spatially adjacent information. Robust application of such techniques will eliminate the extrema of valid observations as well as those which are erroneous, while weaker application increases the risk that a progressively greater number of errors will fail to be caught.

More accurate and more complete surface wind field and air quality data would have enabled more accurate estimates of residence time and transport. However, the problem of lack of such data at above-surface levels would still remain. Thus, more complete assessment of air parcel transport and residence time in the SoCAB would require both additional data and/or mesoscale model output not available to us as part of the present project. In order to accurately estimate the transport, it is necessary to know the evolving three-dimensional structure of the wind field over the region of interest. Moreover, in an area such as the SoCAB where the topography strongly modulates the flow, and where the orographic features are significant on small spatial scales, it is necessary that the wind field information be of high temporal and spatial resolution. Further, assessment of transport necessitates knowledge of ozone concentrations at levels above the surface.

There are three possible approaches to acquiring the requisite information. The first is strictly observational. Here, wind and ozone data are acquired three-dimensionally over the region of interest. Thus far this has only been done for special projects such as SCAQS. Even then, data have generally not been of sufficient resolution to well-define the evolving pollutant and wind field structures at above-surface levels. To rectify this issue on a routine basis would require implementation of substantial additional observational platforms, devices, and techniques (*e.g.*, numerous profilers, rawindsonde launches, aircraft spirals, tracer releases, etc.) The cost of such an undertaking would probably render it prohibitive.

A second approach involves the use of paradigmatic days. Here the objective is to acquire sufficient observational information to well-define transport and residence time for a small number of days which cover the range of meteorological conditions associated with high values of ozone (or other pollutant of interest) within the SoCAB. Such is the general attempt with special observational programs such as SCAQS, but given the comparatively small number of days covered by such programs, and the virtually complete absence of above-surface data on the vast majority of significant air pollution days, it is difficult to assess the degree of similarity with sufficient precision. CART attempts to address this issue, but the question remains as to the actual relevant degree of similarity between days within a given CART node when the decision-tree, as in the present study, substantially utilizes above-surface data and the location of these data is neither specified nor constant within the data set. In addition, of course, there is the question of how well a single sounding can represent the evolving dynamic and thermodynamic structure of the entire SoCAB.

In a third approach, high-resolution primitive equation numerical models can be utilized to further investigate meteorologically-related issues such as transport and residence time. Here the basic approach is to configure the model such that starting with available initial data, and utilizing observationally-defined boundary conditions, it can accurately replicate the evolving air flow within the region of interest. Tests of the accuracy of the model output are enabled by comparison with those cases for which high-resolution observational data are available, as well as less comprehensively by using the data available under routine circumstances. If the model proves to be both accurate on the coarser scale as verifiable in the latter circumstance, and on the finer scale under a representative range of meteorological conditions as verifiable in the smaller number of cases of much more complete data coverage, it would seem justifiable to assume it can competently reproduce the wind field. The high temporal resolution three-dimensional output from the model can then be used as a sort of surrogate data set for finding forward and backward three-dimensional trajectories from and to various locations under a significant range of meteorological conditions. Given the substantial increases in sophistication which have recently occurred in such mesoscale models, along with their comparative ease of use (many can now run on computer workstations in reasonable lengths of time), this is likely to be the most profitable approach in the near future to more thoroughly investigating transport and residence time in a region such as the SoCAB.

Finally we emphasize that further interpretation of our results, in terms of drawing conclusions about the relationship between WD/WE differences in emissions of VOC and NO_x and WD/WE differences in ozone, is difficult due to the significant uncertainties in retroactively constructing accurate WD/WE emission inventories for the study period. This is particularly true for VOC emissions, for which reliable and accurate ambient 6-9 am ambient concentration data are not available for the period investigated (apart from a handful of special studies such as SCAQS). Recent large revisions to mobile source emissions inventories, including "back-casted" increases in VOC, CO, and NO_x emissions from mobile sources during the period of our study, increase the difficulty of reliably defining emissions for these earlier years. Obtaining reliable total emissions data for individual weekdays and weekend days is even more problematic and to date the relevant agencies have been unable to furnish such data in support of this project.

For example, the SCAQMD has provided stationary source emissions for 1987, 1990 and 1994 for both weekdays and weekend days, and on-road mobile source emissions for weekdays. However, the District was unable (through no fault of their own) to provide reliable data for weekend on-road mobile source emissions (Hogo 1996). While a number of investigators have reported emissions data for individual years and by weekday vs. weekend day in both the gray literature and, in a few cases, in the peer-reviewed literature, we remain skeptical about the accuracy and reliability of such data. A recent example is the paper by Altshuller *et al.* (1995) in which emissions of VOC and NO_x are reported by weekday and weekend for 1980 and 1990 for the San Francisco Bay Area to as many as 4 significant figures (*e.g.*, for 1980, ROG: 1591 TPD on weekdays and 1359 TPD on weekends). In view of earlier large (up to 200%), and continuing, revisions in mobile source ROG emissions for California's airsheds, and the inherent difficulties in quantitatively estimating ROG emissions from stationary sources, it is not clear such data, back-casted as much as 15 years, have any real meaning to the number of significant figures reported.

Moreover, while appropriately selected ambient air measurement data allow inferences about emissions, especially in the case of NO_2 and NO_x, the absence of extensive and accurate ambient VOC concentration data make such inferences for VOC emissions problematic except for a few well-documented intensive monitoring studies (*e.g.*, SCAQS). Thus, the failure to establish in the SoCAB a network of accurate non-methane hydrocarbon instruments in the 1970's and 1980's (as called for in the early 1970's by James N. Pitts, Jr., among others) has proven to be a serious limitation to emissions trends analyses.

For these reasons, we have taken the approach of presenting the empirical trends and relationships we have derived from an analysis of robust data sets of measured ambient air concentrations (*e.g.*, for NO_2 and NO_x), but we have declined to move beyond such analyses based on speculative emissions estimates or limited VOC ambient data. We leave such extrapolations to others, or until such time as there is convincing evidence emissions for a given set of past years, and by day of the week, can be reliably estimated.

9.0 RECOMMENDATIONS FOR FUTURE RESEARCH

Based upon the present project we recommend the need for additional research in the following areas:

In order to further our understanding of the meteorological issues investigated in the present study, it is recommended that routine acquisition of observational data be enhanced, and/or that high-resolution mesoscale models be implemented. Both of these options were discussed in some detail in Section 8.3 of this report.

Given the amount of additional information deemed necessary to acquire an accurate assessment of residence time under the range of relevant meteorological conditions, the latter approach (*i.e.*, use of an appropriately-configured mesoscale model) is likely to prove most profitable. It should be made clear, however, that even with the recent improvements in both the degree of sophistication of such models and their ease of use, such a project would represent a substantial undertaking and would need to be supported accordingly.

Although in general they are significantly less sophisticated meteorologically than mesoscale models, airshed models which combine meteorological and air chemistry components have already been used in California to develop State Implementation Plans for ozone nonattainment areas. Control strategy evaluation, however, requires an understanding of how reliably such models can predict changes in air quality that result from changes in emissions. The substantial improvement in air quality that has occurred in the SoCAB, as documented in the present study and elsewhere, allows for a test of the ability of airshed models to predict the impacts of changes in emissions on ozone if meteorologically similar episodes can be found in years with significantly different emissions.

It is therefore proposed that future research be undertaken to develop quantitative air quality trends for meteorologically similar episodes over a wide range of years. Since different subregions of the SoCAB may well exhibit different responses in terms of air quality under meteorologically similar circumstances, it would be advisable to develop these trends by subregion of the SoCAB. (It may also prove useful to more narrowly define certain subregions, for example, the large Metropolitan subregion used in the present study.) Determination of these trends will provide important information on how air quality has actually changed with time. Knowledge of these trends will also enable comparisons with the airshed model predictions.

As a prelude to this work, though, it is necessary to develop a robust functional relationship between ozone concentrations and the various available metrics of the meteorological conditions (since it is meteorological similarity with respect to the occurrence of ozone that is of relevance here). Once determined, this relationship can then be used to identify meteorologically-similar ozone episodes.

Further analyses of the kind conducted in the present study should incorporate ambient concentration data for carbon monoxide, non-methane hydrocarbons and particulate matter, as well as oxides of nitrogen. In this regard reliable and systematic monitoring of ambient VOC concentrations continues to be a priority need in order to (a) permit assessment of the accuracy of VOC emissions inventories generated from mobile source emissions models and stationary source emission factors, and (b) monitor trends in the VOC inventory over time.

In the present study, it was assumed SoCAB meteorology was the same on weekdays and weekends (consistent with all previous studies of this kind). Future research should consider whether evidence exists for differences in SoCAB micrometeorology between weekdays and weekends due to influences such as aerosol and heat island effects. Such an analysis would require addition of data for aerosol concentrations (*e.g.*,beta-gauge PM-10 sampler data) and solar radiation intensity data.

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