THE ORIGIN AND FATE OF AIRBORNE POLLUTANTS WITHIN THE SAN JOAQUIN VALLEY

VOLUME 3 - WINTER FIELD STUDY

by

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Characteristic wind flow in the valley during stable periods is toward the center of the valley and northward at night. By late forenoon, the flow in the southern end of the valley usually becomes northwesterly with upslope components. The latter provides a mechanism for removal of low level air from the valley during the daytime.

Tracer releases from Fresno and Chowchilla during the November-December program showed similar characteristics. A slow drift toward the north was observed during the late afternoon and evening. A slow drift toward the south occurred during the following morning. Most of the tracer appeared to be within a 70 mile radius of the release site after 24 hours. During the afternoon of the day following release the tracer diluted rapidly by vertical mixing.

Releases in the southern end of the valley (Bakersfield, Valley Acres and Lost Hills) showed the influence of afternoon upslope winds. Tracer material was carried upslope during the afternoon but much of it returned to the valley during the evening in drainage flow. During the night the drainage winds carried the material across the valley. On occasion, the material appeared on the opposite side of the valley by early forenoon. By late forenoon the tracer material spread throughout the southern end of the valley and was carried upslope by the characteristic afternoon wind pattern.

Two additional tracer releases were carried out in February and March 1979 but without meteorological and air quality support. More pronounced stability resulted in longer residence times in the valley than observed in the November-December period. It was estimated that 1/2 of the tracer material remained in the valley after 60 hours.

ABSTRACT

An extensive observational program was started in 1978 to investigate the origin and transport of pollutants in the San Joaquin Valley. Three field programs were carried out. The present volume (Volume 3) describes the results of the 15 November to 10 December intensive field study. Volumes 4 and 5 describe the summer (July 1979) and fall (September 1979) programs, respectively. Participants in the study were Meteorology Research, Inc., California Institute of Technology, Rockwell International (EMSC) and Environmental Research and Technology (ERT).

Five tracer releases provided the core of the November-December field program. These releases were supported by supplementary meteorological observations and airborne air quality sampling. Three Rockwell International vans operated continuously in the valley to provide additional air quality data. Filter samples obtained at each of the vans were analyzed by ERT to evaluate the particulate chemistry in the area.

Overall air pollution conditions in the valley during the November-December field program were analyzed and compared to historical periods from previous years. Temperatures at 850 mb (reflecting the potential for air pollution accumulation) averaged below normal for the field study period but with occasional periods of above normal temperatures. Maximum pollutant concentrations observed during the program were slightly less than those recorded in the valley during November-December 1977 or 1979. It is concluded that the tracer studies were conducted under representative but not extreme pollution conditions for that time of year.

Ozone concentrations observed during the field program were low (maximum .08 ppm) and relatively uniform throughout the valley. CO and NO_x concentrations reflected strong urban sources and were closely related to peak traffic periods. SO_2 concentrations were highest near Oildale. Timing of the SO_2 peaks suggested transport from nearby source areas.

TABLE OF CONTENTS

List of Tables (Continued)

LIST OF TABLES

List of Figures (Continued) Page

LIST OF FIGURES

Two additional tracer tests were carried out by Cal Tech as follows:

Release Location	Date (1979)	Release Time (PST)
Lost Hills	February 6-7	2000-0800
Lost Hills	March 6-7	2030-0800

These tests were conducted outside of the scope of the original contracts and were not supported by meteorology and air quality measurements. They are included in the present report since they provide additional information of value in developing a year-round understanding of dispersion in the valley.

The present volume (Volume 3) discusses the details of the winter field program including all pertinent tracer and aircraft sampling data. Surface and pibal wind data have been furnished to CARB on magnetic tape. Separate reports (Volumes 6 and 7) give the details of the Rockwell International and ERT work, respectively. Portions of these reports have been used in the present volume, where appropriate.

Volumes 4 and 5 of the report series include the details of the summer and fall intensive programs, respectively. Volume 2 provides an extended summary of the entire program and a discussion of a number of special analysis topics which resulted from the field measurement programs. Volume 1 is an Executive Summary of the program.

1. Introduction

Winter months in the San Joaquin Valley are characterized meteorologically by stable periods with light winds interrupted by occasional cold frontal passages with moderate to strong winds. These frontal passages scour out the valley and effectively remove most of the pollutants. The effectiveness of the stabilizing process after a frontal passage is evidenced by the rapid decrease in visibility throughout the valley. These restricted visibility periods continue until the next trough passage.

The stable, light wind periods between trough passages offer the potential for air pollution build-up. The restricted visibilities provide some evidence of the potential problem. A winter intensive field program was carried out in November-December 1978 to evaluate the extent of this problem.

The objectives of the winter field program were:

1. To investigate the transport and dispersion characteristics in the valley.
2. To evaluate the ventilation budget of the valley.
3. To characterize the air quality and the particulate chemistry during the winter periods.

In view of the difficulties in carrying out a field program covering the entire valley, the winter program was concentrated in the southern half where the greatest potential for pollutant build-up seemed to exist.

The winter field program consisted of five tracer releases as listed below. Each release was supported by pibal wind soundings and aircraft measurements which provided air quality and temperature structure information. Three Rockwell International air quality vans were positioned at Reedley, the Rockwell Radome facility south of Bakersfield and at Lost Hills. Environmental Research and Technology (ERT) provided filter samplers which were operated at each van. Analyses and interpretation of the filter samples were carried out by ERT.

The following tracer releases were carried out during the winter program:

Release Location	Date (1978)	Release Time (PST)
Chowchilla	November 15	1100-1600
Fresno	November 18	1200-1700
Bakersfield	November 25	1200-1700
Valley Acres	November 29	1200-1700
Lost Hills	December 8	1400-2030

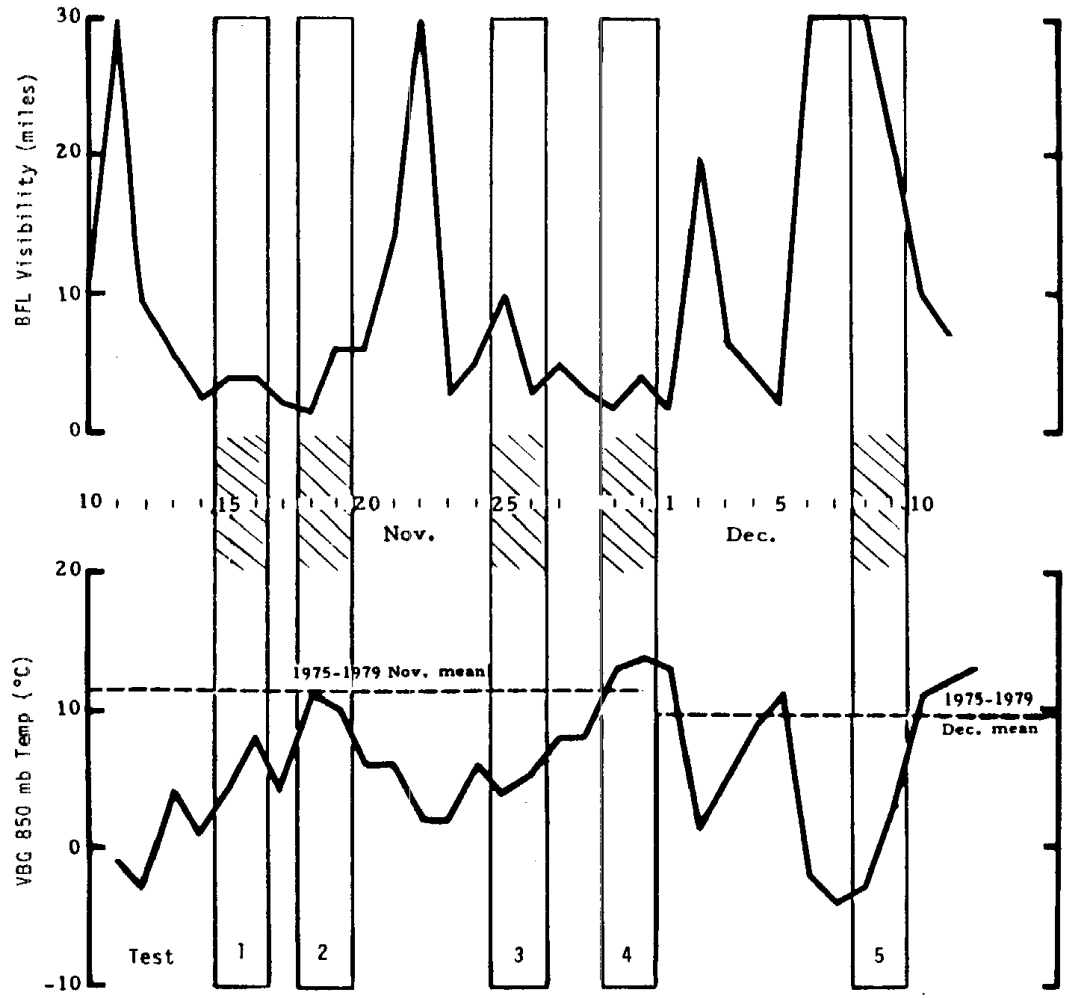


Figure 2.2.1 850 mb Temperatures and Visibilities
November-December 1978

2. Overview of Meteorology and Air Quality

2.1 Introduction

The following sections describe the general conditions which occurred during the winter intensive field period in November-December 1978. The overall meteorological conditions are summarized and compared to climatological records to determine the representativeness of the test period. Descriptions of air quality and particulate concentrations for the intensive period are summarized from the more extensive reports by Rockwell International and ERT which appear as Volumes 6 and 7 of this report.

2.2 Meteorology

850 mb Temperatures

Late fall and early winter in the San Joaquin Valley are characterized by stable periods punctuated by occasional cold frontal passages. During these intrusions of cold air, instability and strong winds tend to scour out the valley, removing most of the pollution which accumulates during the stable periods.

Figure 2.2.1 shows the distribution of 850 mb temperatures at Vandenberg AFB for the period of November-December 1978. Such temperatures have been used frequently (e.g., Smith, Giroux and Knuth, 1977) to characterize regional air pollution potential. Warm temperatures aloft lead to stable temperature lapse rates and greater potential for trapping of pollutants in the surface layers. November and December mean 850 mb temperatures are included in Figure 2.2.1 for a comparison with climatology. The data indicate that the November-December 1978 period had lower average 850 mb temperatures than normal but showed some periods of above average temperatures.

Tracer test periods are shown in block form in Figure 2.2.1. All tests were conducted in relatively stable periods with the exception of Test 5 which was carried out in a rapidly stabilizing situation where the first two days of the test period differed considerably in their stability characteristics.

From Table 2.2.1 it can be seen that the stagnation tends to be a valley-wide phenomenon with some tendency for the southern part of the valley to be affected to a greater degree.

In comparison with the data in Table 2.2.1, the following table shows the climatological occurrence of such stagnation episodes.

Table 2.2.2

CLIMATOLOGICAL STAGNATION EPISODES
(1967-77)

		Mean No. Days Per Month	Maximum Duration in 11-Year Period
Stockton			
	November	14.4 days	10 days
	December	19.3	16
Fresno			
	November	20.6	19
	December	20.0	19
Bakersfield			
	November	16.6	14
	December	18.9	18

Comparison of the stagnation episode data in the two tables indicates near normal but not extreme conditions during the November-December 1978 field period.

Surface Winds

Under conditions where synoptic pressure gradients do not influence the valley (conditions of restricted visibility) diurnal patterns in the surface wind patterns were apparent in the November-December intensive period. These patterns are illustrated in typical fashion for the southern part of the valley in Figures 2.2.2 and 2.2.3.

During the night (Figure 2.2.2) drainage winds occur on both sides of the valley creating an apparent zone of convergence near the center (indicated by dashed line). The nature and structure of the zone are unclear. Essentially,

Visibilities

Figure 2.2.1 includes a plot of the 1300 PST visibility at Bakersfield for the November-December 1978 period. During the winter, restricted visibility in the valley is a simple indicator of the extent of the pollutant trapping which exists on any given day. It is to be noted in the figure that the visibility plot during the two-month period has a very strong negative correlation with respect to the 850 mb curve. Warm temperatures aloft correlate extremely well with restricted visibilities. It is apparent from the figure that the result of the cold air trough passages is to flush out the valley from a pollutant standpoint. Major cases of flushing (November 22, December 2 and December 6-8) are associated with the lowest 850 mb temperatures at Vandenberg. The rapidity of the stabilizing influence following a trough passage is apparent in the rapid return to low visibilities following the cold air intrusion.

The visibility trends during the winter can therefore be used as an indicator of the degree and frequency of flushing of the valley. For this purpose, a criterion was established which defined the existence of flushing as a day on which the visibility achieved a level of 10 miles or more at any time during the day. This arbitrary definition then permits the length of stagnation (pollutant-accumulation) periods to be tabulated.

According to this definition, stagnation periods occurred during the field intensive period as follows:

Table 2.2.1

STAGNATION PERIODS

Stockton		Fresno		Bakersfield	
November 13-20	(8 days)	November 14-18	(5 days)	November 12-17	(6 days)
November 25-30	(6 days)	November 24-30	(7 days)	November 20-30	(11 days)
December 4	(1 day)	December 4	(1 day)	December 5-8	(4 days)
		December 10	(1 day)		
Total	15 days		14 days		21 days

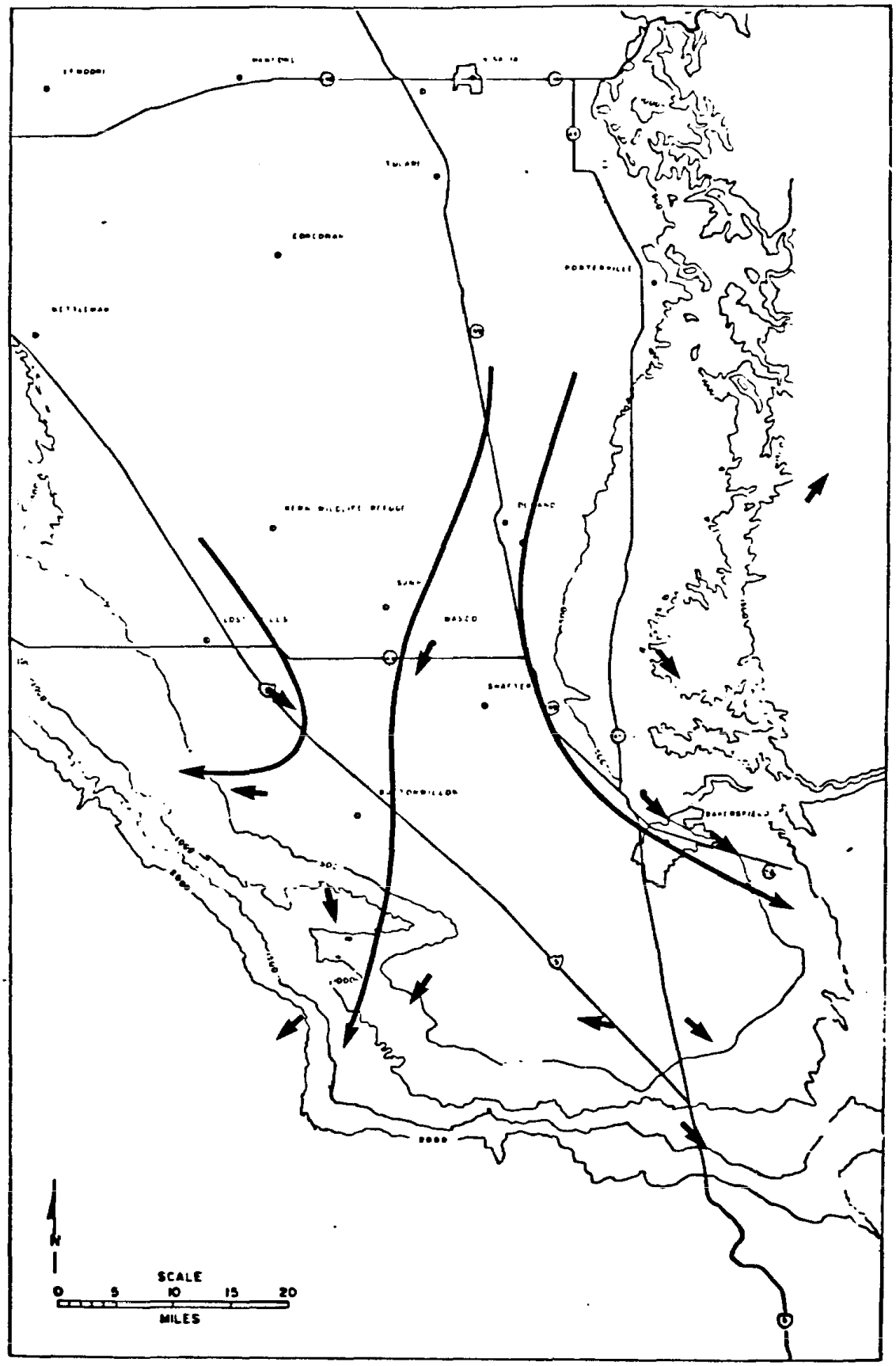


Figure 2.2.3 Surface Streamlines - 8 December 1978 (13 PST)

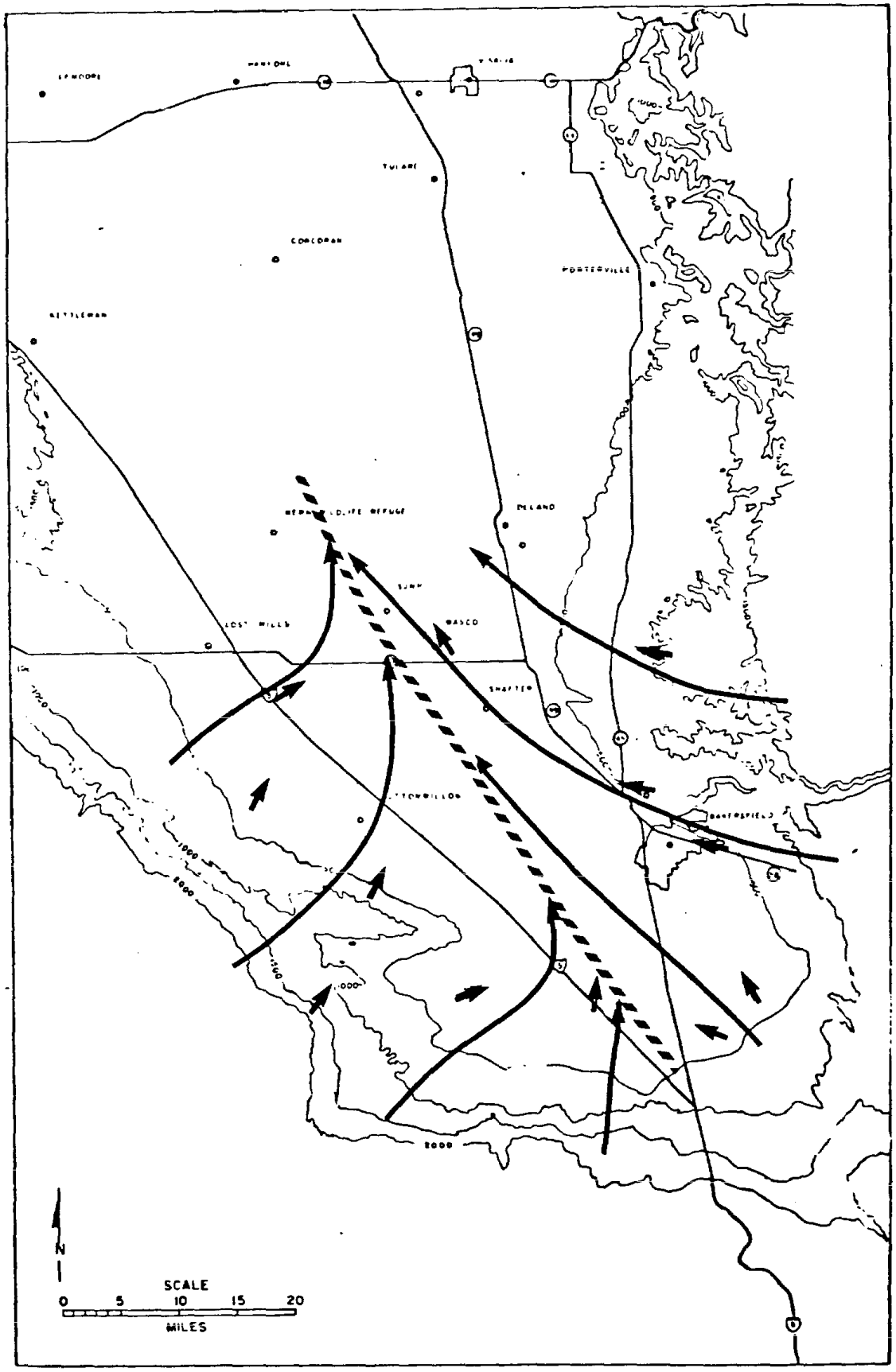


Figure 2.2.2 Surface Streamlines - 8 December 1978 (22 PST)

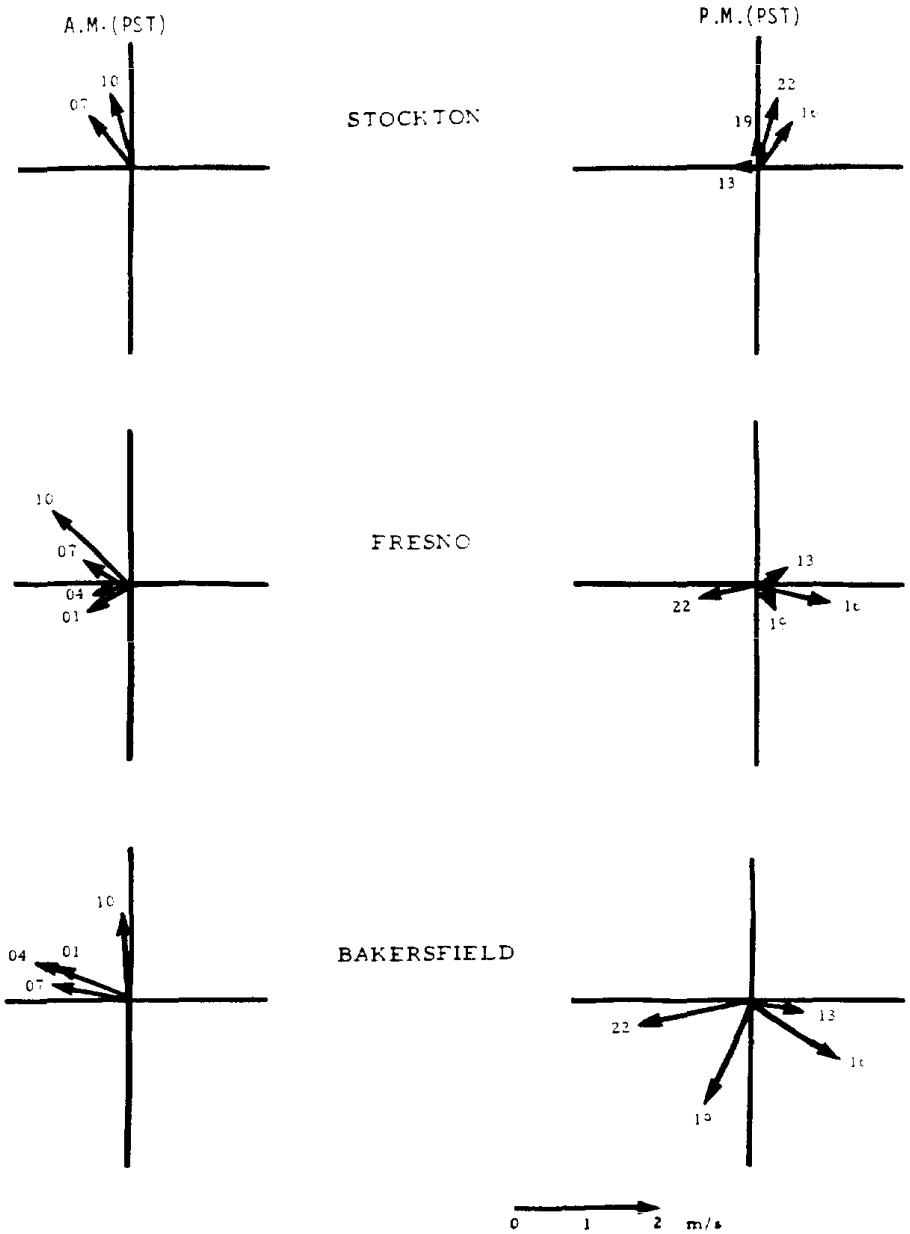


Figure 2.2.4 Resultant Surface Winds - Low Visibility Conditions
November-December 1978

two dense layers of air flow down the slopes toward the center of the valley. The nature of the interaction between the two fluid streams depends on the relative densities of the streams as well as their velocity fields. These may vary somewhat from night to night.

During the forenoon the drainage flow is eliminated and is replaced by an upslope flow (Figure 2.2.3). As indicated, the flow is upslope in all directions and suggests that some air (and pollutant material) can be transported out of the valley during a part of the day.

If the low visibility days (visibility <10 miles at 1300 PST at each location) are considered as a separate data set for the intensive period, resultant surface winds for various hours of the day at Stockton, Fresno and Bakersfield are shown in Figure 2.2.4. Diurnal changes in wind direction are apparent at each location, particularly at Fresno and Bakersfield. Afternoon winds tend to have a westerly component while night and early morning hours show an easterly component. As indicated in the figure, the net flow at Stockton is clearly from the south (out of the valley) over a 24-hour period. At Fresno, the net flow is from the south but to a lesser degree than at Stockton. Primary diurnal fluctuations occur in a cross-valley direction. At Bakersfield, the net flow over a 24-hour period is near zero in a north-south direction but with a slight net component from the south. This characteristic increase in southerly flow from south to north within the valley is consistent with the concept that the mass drainage flow may be additive with distance from south to north within the valley.

In any event, the low-level flux into the northern end of the valley, during significant pollution periods, appears to be negative, i.e., low-level air tends to flow out of the valley. This suggests that transport from the industrial source areas in central California is not a significant contributor to the San Joaquin valley during the winter stagnation periods.

Mixing Depths

Measurements of the mixing depths were made by the aircraft on a number of occasions during the intensive period. Most of the observed depths ranged between 500 and 800 m above ground level with a few as deep as 1200 m. These depths apply to the stagnant periods between trough passages and should be considered typical of these conditions.

Table 2.3.1

MAXIMUM HOURLY CONCENTRATIONS
(NOVEMBER-DECEMBER)

Location	O_3(ppm)			CO (ppm)		
	1977	Field 1978	1979	1977	Field 1978	1979
Bakersfield		.06	.07	18	16	17
Coalinga	.07	.06	.08	4	4	5
Five Points	.08	.06	.06	2	5	2
Fountain Springs		.08				
Squaw Valley	.10	.06				
FNO-Butler		.07				
FNO-CSU		.05			13	
FNO-Downtown		.06				
FNO-Olive	.08	.05	.05	23	18	28
Hanford		.05	.09			
Lindsay	.08	.06				
Los Banos	.07	.06	.08			
McKittrick		.08				
Merced	.07	.06		11	7	
Modesto	.04	.03	.06	22	13	18
Oildale		.05	.08	7		
Shaver Lake	.09	.05				
Stockton				21	10	18
Taft		.03	.07			
Turlock	.07	.06	.05			
Visalia	.08	.07	.10	15	11	12
Reedley		.07			3.6	
Radome		.07				
Lost Hills		.07				

2.3 Air Quality

Tables 2.3.1 and 2.3.2 give the maximum hourly concentrations of various parameters as observed during the winter intensive field program (November 15 - December 10, 1978). Concentrations observed at Reedley, Radome and Lost Hills are also included as determined by the Rockwell International vans. For comparison the maximum concentrations for November-December 1977 and 1979 are shown where available.

Comparison of the data obtained during the field period with 1977 and 1979 data indicates that, in almost every case, peak concentrations during the field program were slightly less than occurred in 1977 and 1979. This conclusion corresponds with that reached in the previous section, i.e., the meteorological conditions were slightly less conducive than average to high pollutant potential although a number of relatively high pollutant days were experienced.

Ozone

Maximum hourly concentrations shown in Table 2.3.1 indicate a narrow range of values throughout the valley. In keeping with the lateness of the season, photochemistry effects are small compared to summer and fall periods. Even the major urban downwind areas do not show the effects of significant ozone increases. Similar results are shown for 1977 and 1979 although there are some indications that downwind areas (Shaver Lake, Squaw Valley) experienced slightly enhanced ozone values.

There were a number of occasions when concentrations of ozone, NO and NO_2 were all less than 10 ppb. Most of these occurred after midnight. One such case is shown for Reedley on December 3:

Hourly Concentrations (ppb) - December 3, 1978

	Reedley		
Time (PST)	O_3	NO	NO_2
00	3	1	2
01	1	4	2
02	1	1	0
03	3	0	0
04	5	0	0
05	4	0	0
06	1	1	0
07	2	1	-

In this case the small quantities of nitrogen oxides do not indicate a reactive depletion of the ozone. Similar occurrences are observed in some of the rural areas where CARB stations are located. For example, at Squaw Valley most of the ozone concentrations recorded between midnight and 04 in November and December were 0 or 1 pphm. The data appear to indicate that the background levels of ozone in the valley during winter may be somewhat below the values of .03 to .04 ppm usually quoted or that another depletion mechanism may exist.

CO

In contrast to the ozone concentrations, the CO values in Table 2.3.1 show the marked influence of urban areas. All of the large values reported are associated with metropolitan areas. On the other hand, values at Coalinga and Five Points are much lower. The peak concentration of 3.6 ppm at Reedley (often downwind of Fresno) indicates the rapid dilution of the urban plume upon moving into the rural areas.

The urban-rural differences are also shown in Table 2.3.3 which gives the daily CO maximum at several stations during a low-visibility episode which began on December 7, 1978. CO maxima at Fresno-Olive increased to a peak of 22 ppm whereas the rural areas showed much lower increases. The increases in CO during the episode do not reflect accumulation of CO in the valley. The 850 mb temperature at Vandenberg AFB peaked on December 12 so that variations in stability and pollution potential accounted for most of the changes shown in Table 2.3.3.

Table 2.3.3

DAILY CO MAXIMUM - DECEMBER 7-15, 1978
(ppm)

	Reedley	Fresno-Olive	Five Points
December 7	2.1	9	1
8	2.4	18	1
9	2.7	13	2
10	3.6	13	1
11	3.5	14	2
12	1.8	22	2
13	2.4	17	2
14	2.7	16	1
15	2.5	13	1

Table 2.3.2

MAXIMUM HOURLY CONCENTRATIONS
(NOVEMBER-DECEMBER)

Location	NO_x (ppm)			SO_2 (ppm)		
		Field			Field	
	1977	1978	1979	1977	1978	1979
Bakersfield	1.13	.90	1.05	.07	.05	.09
Coalinga	.11	.09	.17			
Five Points				.03		
FNO-Downtown		.67				
FNO-Olive	1.03	.88	1.46		.04	.12
McKittrick					.08	
Merced	.50	.40				
Modesto	.94	.62	.86		.03	.03
Oildale				.17	.15	.16
Stockton	.87		.73			
Visalia	.62	.55	.56			.04
Reedley		.31			.02	
Radome		.13			.01	
Lost Hills		.18			.005	

Time of Peak Hourly Concentrations

Table 2.3.5 gives the principal period of the day when peak concentrations were observed at the three van sites and for selected CARB monitoring sites.

For ozone, the peak ozone concentrations occurred during the late forenoon to early afternoon, indicating the local nature of the sources involved. In the case of CO and NO_x, peak concentrations were observed at times of morning or evening traffic periods. The similarity between CO and NO_x peaks suggests mobile emissions as the primary source of these two pollutants.

As indicated in Table 2.3.5, the timing of the SO_2 peaks varies considerably from location to location. At Modesto and Fresno, the peaks occur toward the end of the evening traffic period and are relatively small (.04 ppm or less). At other locations, the timing appears to be related to the diurnal wind patterns and the relation of the receptor area with respect to nearby source areas.

Table 2.3.5
TIME OF MAXIMUM CONCENTRATION (PST)
NOVEMBER-DECEMBER 1978

	O_3	CO	NO_x	SO_2
Reedley	10-16	07-09	16-21	11-15
Radome	11-16		04-09	12-17
Lost Hills	10-16		06-12	05-11
Bakersfield	12-15	17-21	17-23	10-19
Fresno-Olive	12-15	18-22	17-23	06-11
Oildale	12-15		17-22	09-12
McKittrick				19-21
Modesto	14-15	18-21	18-22	19-21
Stockton		17-20	18-21	
Visalia	12-15	18-21	18-21	

Nitrogen Oxides

Observed maximum hourly concentrations of NO_x during the winter intensive program are given in Table 2.3.2 and are compared to November-December maxima recorded in 1977 and 1979. As before, maximum values found during the 1978 winter program are somewhat below those recorded in 1977 and 1979. The urban-rural differences are clearly shown. The Radome and Lost Hills sites appear to be representative of rural areas as far as NO_x is concerned.

Table 2.3.4 shows the maximum values of NO, NO_2 and NO_x observed at the three Rockwell International sites. The data indicate that peak concentrations of NO exceeded NO_2 at all sites and served as the main contribution to NO_x during maximum NO_x concentration periods.

Table 2.3.4

MAXIMUM NITROGEN OXIDES CONCENTRATIONS (ppm)

NOVEMBER-DECEMBER 1978

	Reedley	Radome	Lost Hills
NO	.31	.11	.14
NO_2	.08	.05	.05
NO_x	.31	.13	.18

Sulfur Dioxide

Sulfur dioxide maximum hourly concentrations are also shown in Table 2.3.2. The strong source area near Oildale is immediately apparent. Considerable dilution occurs, however, by the time the Bakersfield and Radome sites experience the Oildale plume.

PAN

Peroxyacetyl nitrate (PAN) was measured only at Reedley. It was continuously monitored over the period 12 November through 20 December. The highest concentration recorded was 14.1 ppb. The highest levels reached for more than one-half hour were 5 to 6 ppb. The most common temporal behavior was a low concentration (below 3 ppb) all day. On some days a single peak occurred from 14 to 18 PST while a double peak (12-14 PST and 15-21 PST) was occasionally observed. These values are below those found in such urban areas as Los Angeles and St. Louis but somewhat above those measured in rural areas of Ohio and the Netherlands.

Direct emissions of particles from motor vehicle exhaust contributed a small amount to the total particle samples at all three sites. The contribution was largest at Fresno, as expected from the lead concentrations discussed in Table 2.4.1.

Contributions of direct emissions of particles from oil combustion were also small at all sites, comprising 1 percent or less of the mass. The contributions were larger at Bakersfield and Lost Hills than at Fresno, as expected from the nearby presence of oil field operations. Ammonium sulfate formed from atmospheric transformation of SO_2 emissions accounted for about 10 percent of the mass at all three sites. Ammonium nitrate, a secondary product of atmospheric reactions, accounted for 14-36 percent of the mass at the three sites. Concentrations of ammonium nitrate, which is formed from emissions of nitrogen oxides, were about equal at Fresno and Lost Hills. As a result of the lower average mass concentration at Lost Hills, ammonium nitrate comprised a larger fraction of the mass than at Fresno. The average ammonium nitrate concentration at Bakersfield was 43 percent of the concentrations at the other sites.

Carbon from sources other than those included in the calculations accounted for about 7 percent of the mass at Bakersfield and Lost Hills and 19 percent of the mass at Fresno. Possible sources of this carbon include:

- Inaccuracies in the emission composition used for tertiary oil recovery boilers using fuel oil
- Organic compounds formed by atmospheric reactions
- Emissions from vegetative burning
- Emissions from diesel engines if the ratio of diesel vehicle emission to automobile emissions affecting the samples was larger than the ratio on which the motor vehicle source composition is based

Excluding this excess carbon, sources not included in the calculations accounted for 16 to 23 percent of the average measured mass concentrations in the samples.

2.4 Particulates

2.4.1 Total Particle Composition

Average concentrations measured during the November-December intensive are listed by sampling location in Table 2.4.1.

The major components at all three sites include nitrate, sulfate, ammonium, carbon and silicon. Of these commponents, nitrate, carbon and silicon show the largest differences between sites. Substantially lower nitrate concentrations were observed at Bakersfield. Carbon was significantly higher at Fresno than at the other two sites, with the averages at Bakersfield and Lost Hills being about the same. The highest average silicon concentration occurred at Bakersfield. The average at Fresno was 54 percent of the value at Bakersfield, and the average at Lost Hills was 32 percent of the Bakersfield average. A similar pattern is present in the site-to-site differences in the other crustal-like elements.

The largest average concentrations of vanadium and nickel were observed at the Bakersfield site. Significantly lower concentrations were measured at Fresno and Lost Hills. This result for Bakersfield is consistent with the relatively nearby location of major oil fields. The similarity between Lost Hills and Fresno is somewhat surprising, since the Lost Hills site was expected to be affected by operations at the westside oil fields.

Lead and bromine concentrations were highest at Fresno. This result suggests motor vehicles affected that site substantially more than the other sites.

2.4.2 Source Contributions to Total Particle Concentration

Averages of the estimated contributions of the source types to total particle samples from the November-December intensive sampling period are shown in Table 2.4.2. The mass concentration and the fraction of the measured mass from each emission type are listed.

Fugitive emissions of crustal-like materials accounted for substantial fractions of the mass at all three sites. The largest contributions in terms of mass fractions and concentrations were at Bakersfield. Contributions of emissions from cultivated land were somewhat larger than contributions from uncultivated land at Fresno and Bakersfield. The relative importance of these emissions was the opposite at Lost Hills.

Table 2.4.2

ESTIMATED CONTRIBUTIONS OF SOURCE TYPES TO
AVERAGE TOTAL PARTICLE MASS DURING NOVEMBER-DECEMBER 1978

Source Type	Location					
	Fresno (23 Samples)		Bakersfield (16 Samples)		Lost Hills (11 Samples)	
	($\mu g/m^3$)	(%)	($\mu g/m^3$)	(%)	($\mu g/m^3$)	(%)
Cultivated land	16.0	11.0	37.0	31.0	6.0	6.0
Uncultivated land	12.0	8.0	25.0	21.0	15.0	15.0
Motor vehicles (primary)*	4.0	3.0	1.0	1.0	1.0	1.0
Oil combustion (primary)**	0.8	0.5	1.0	1.0	1.0	1.0
$(NH_4)_2 SO_4$	15.0	10.0	12.0	10.0	13.0	13.0
$NH_4 NO_3$	37.0	25.0	16.0	14.0	37.0	36.0
Unidentified C	28.0	19.0	7.0	6.0	8.0	8.0
Sum	113.0	77.0	99.0	84.0	81.0	79.0
Measured Mass	146.0		118.0		102.0	

* Includes only motor vehicle exhaust. Resuspended road dust is not distinguishable from cultivated and uncultivated land. Conversion of NO_x emissions to nitrate is included with NH_4NO_3.

** Sulfate formed from SO_2 emissions and nitrate formed from NO_x emissions is included with $(NH_4)_2 SO_4$ and $NH_4 NO_3$.

Table 2.4.1

AVERAGE TOTAL PARTICLE (diameter $\lesssim 20\ \mu m$)
CONCENTRATIONS MEASURED DURING NOVEMBER-DECEMBER 1978 INTENSIVE

Component	Location					
	Fresno (25 Samples)		Bakersfield (16 Samples)		Lost Hills (12 Samples)	
	($\mu g/m^3$)	(% of Mass)	($\mu g/m^3$)	(% of Mass)	($\mu g/m^3$)	(% of Mass)
Mass	151		118		87.3	
$SO_4^{=}$	13	8.6	8.6	7.3	9.4	10.8
NO_3^-	31	20.5	11.8	10.0	25.1	28.8
NH_4^+	13	8.6	9.1	7.7	10.0	11.5
C	26	11.2	7.3	6.2	5.9	6.8
Al	2.3	1.5	4.0	3.4	1.1	1.3
Si	6.3	4.2	11.6	9.8	3.7	4.2
Cl	0.18	0.1	0.11	0.09	0.040	0.05
K	0.93	0.6	1.3	1.1	0.42	0.5
Ca	0.84	0.6	1.8	1.5	0.76	0.9
Ti	0.13	0.08	0.30	0.3	0.072	0.08
V	0.028	0.02	0.050	0.04	0.037	0.04
Fe	1.22	0.8	3.1	2.6	0.75	0.9
Ni	0.032	0.02	0.050	0.04	0.034	0.04
Zn	0.094	0.06	0.050	0.04	0.025	0.03
Br	0.36	0.2	0.064	0.05	0.031	0.04
Pb	1.3	0.9	0.32	0.3	0.21	0.2
Sum of Observed Components	96.7	64.0	59.5	50.5	57.6	66.0

WEDNESDAY, NOVEMBER 15, 1978

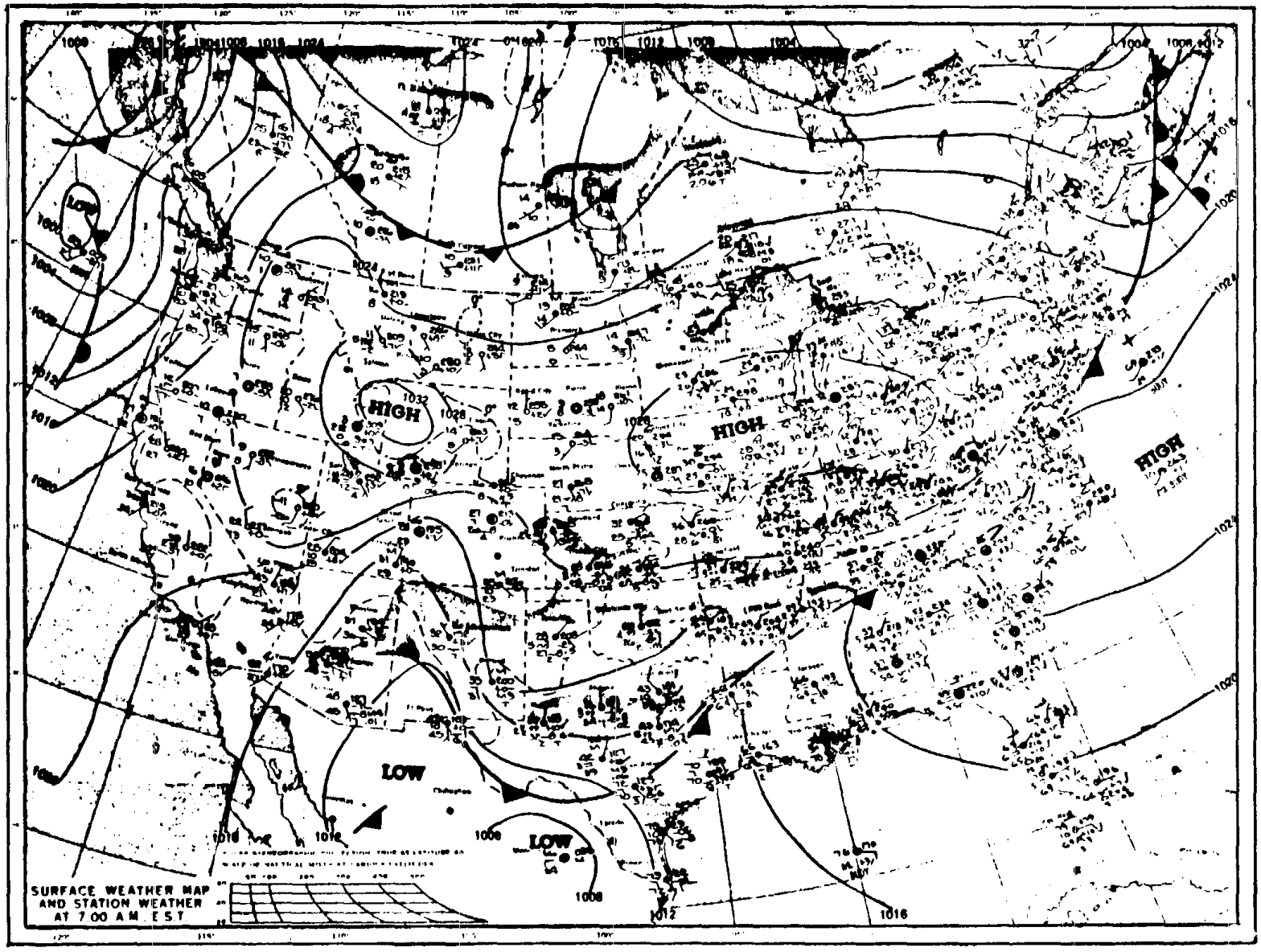


Figure 3.1.1 Surface Weather Map - November 15, 1978

3. Tracer Summaries

3.1 Test 1 15-16 November 1978 - Chowchilla Release (1100-1600 PST)

3.1.1 Meteorology

General

This test was conducted at the beginning of a stabilizing period which followed a storm passage through the area on 13 November. On the morning of the 15th, a closed low aloft at 500 mb was located in northern Arizona and was moving rapidly to the northeast. As can be noted in Section 2, the 850 mb temperature, although reflecting the cold temperatures associated with the earlier trough passage, was on the increase; warming 4°C by the morning of the 16th. Temperatures at 850 mb, however, remained below the 5-year average for November. On the surface (Figure 3.1.1), weak regional pressure gradients were present resulting in weak synoptic scale flow. Locally induced forces thus dominated the wind regime in the valley. At the airport in Fresno, the sky was obscured in the morning by dense fog which burned off by release time and mostly clear or scattered cloud conditions prevailed the remainder of the day. Visibilities ranged from 1/16 of a mile in fog to 5 miles restricted by haze in the afternoon. The high surface temperature measured at Fresno was 58°F as compared to a November average of 67°F. The following morning visibilities were restricted to 2-1/2 miles by fog but increased in the afternoon to 5 miles in haze. The sky was overcast in the afternoon due to the passage of the remnants of a weak weather system.

Transport Winds

Figures 3.1.2 to 3.1.4 show several surface streamline maps for the northern portion of the valley during and after the tracer release period. During the early part of the release, winds at the Chowchilla release site were southerly (Figure 3.1.2). Near the end of the release period the surface wind velocities at Chowchilla decreased substantially. Figure 3.1.3 (1900 PST) is typical of the conditions in the valley during the early evening. Winds at Chowchilla remained light (1.0 m/s or less) throughout the night until 0900 PST on November 16. Beginning about 1200 PST surface winds at Chowchilla increased in velocity from southwesterly to northwesterly directions. These are shown in Table 3.1.1:

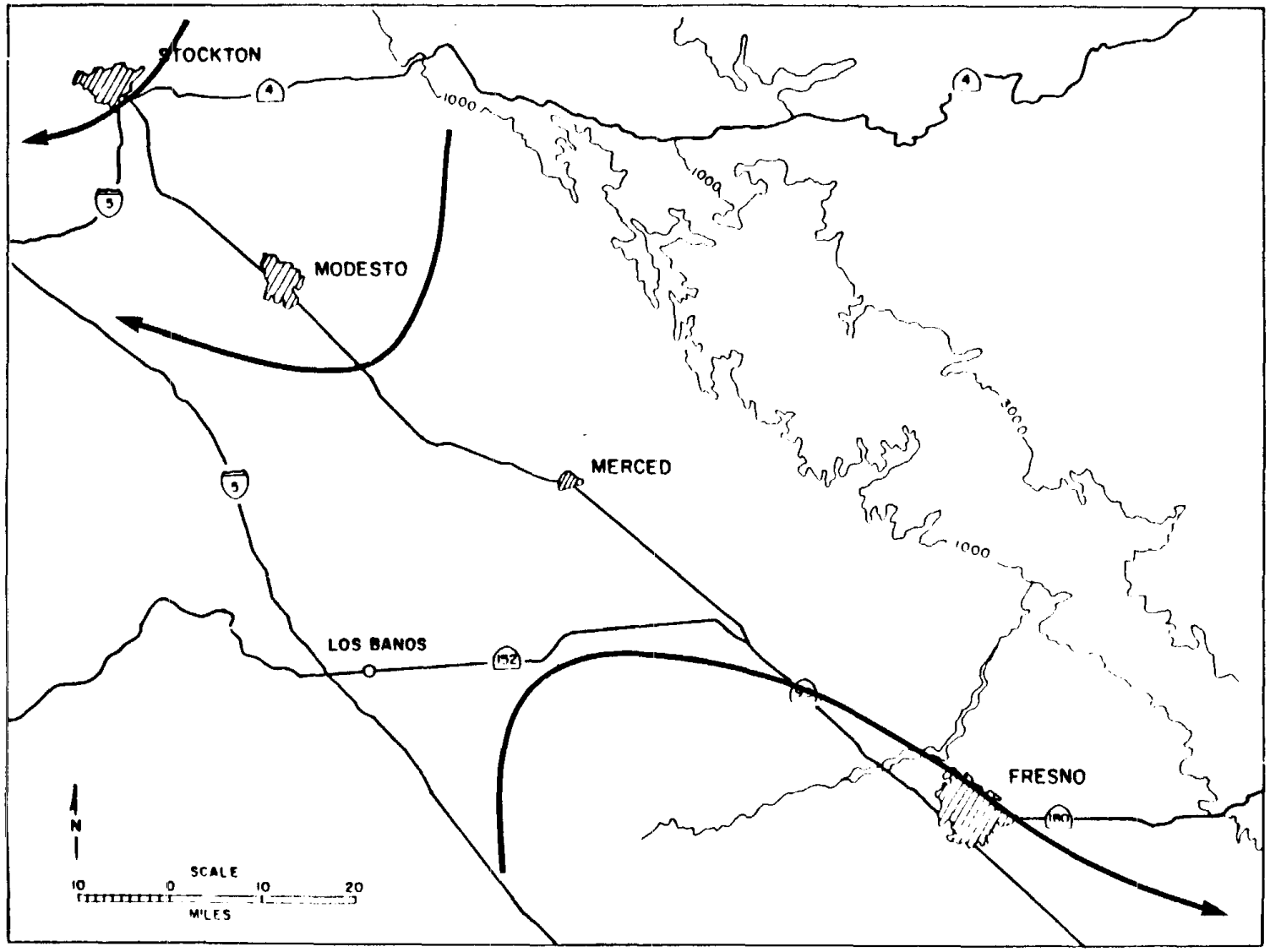


Figure 3.1.3 Surface Streamlines - 15 November 1978 (19 PST)

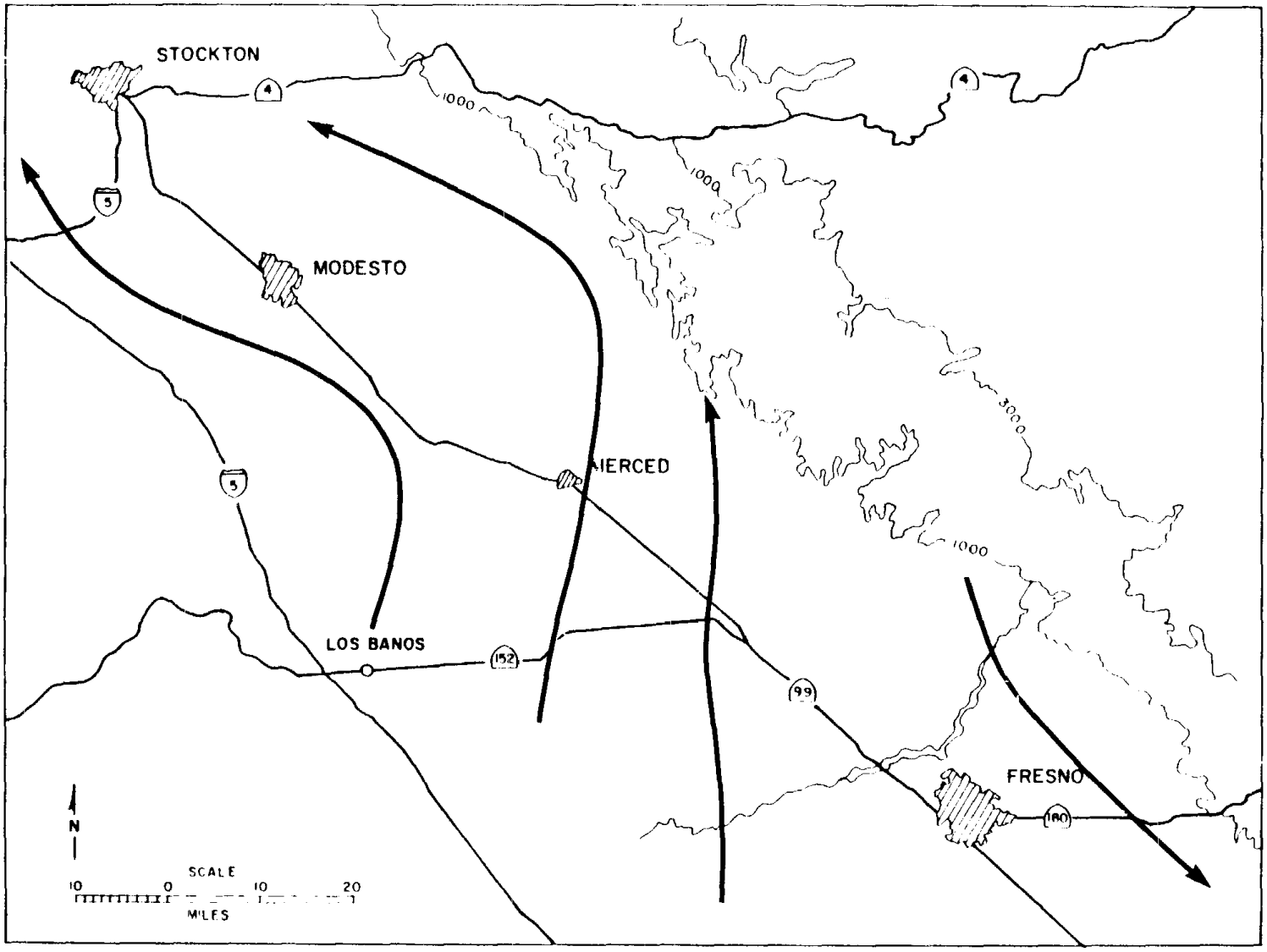


Figure 3.1.2 Surface Streamlines - 15 November 1978 (13 PST)

Table 3.1.1

SURFACE WINDS AT CHOWCHILLA
NOVEMBER 16, 1978

Time (PST)	Wind	Time (PST)	Wind
1200	336°/1.1 m/s	1700	300°/0.8 m/s
1300	207 /1.7	1800	307 /1.1
1400	304 /1.3	1900	339 /2.2
1500	277 /1.2	2000	341 /2.4
1600	235 /1.1	2100	322 /2.0

As shown in the table the northwesterly flow gradually became better established during the afternoon resulting in the transport of tracer material toward the southeast. Figure 3.1.4 shows the streamline pattern at 1900 PST on November 16 with the northwesterly flow well established.

Available winds at 1000 ft are shown in Table 3.1.2 for Fresno and Chowchilla for the period of the release until early morning on November 16.

Table 3.1.2

1000-FOOT WINDS

Date	Time (PST)	Fresno Wind	Chowchilla Wind
11-15	11	227°/1.7 m/s	64°/1.2 m/s
	12		103 /2.8
	13	89 /0.8	168 /1.9
	14		186 /1.7
	15	74 /0.5	217 /1.5
	16		345 /0.5
	17	305 /1.9	351 /1.4
	18		45 /1.4
	19	338 /1.7	326 /0.4
11-16	05	260 /1.0	

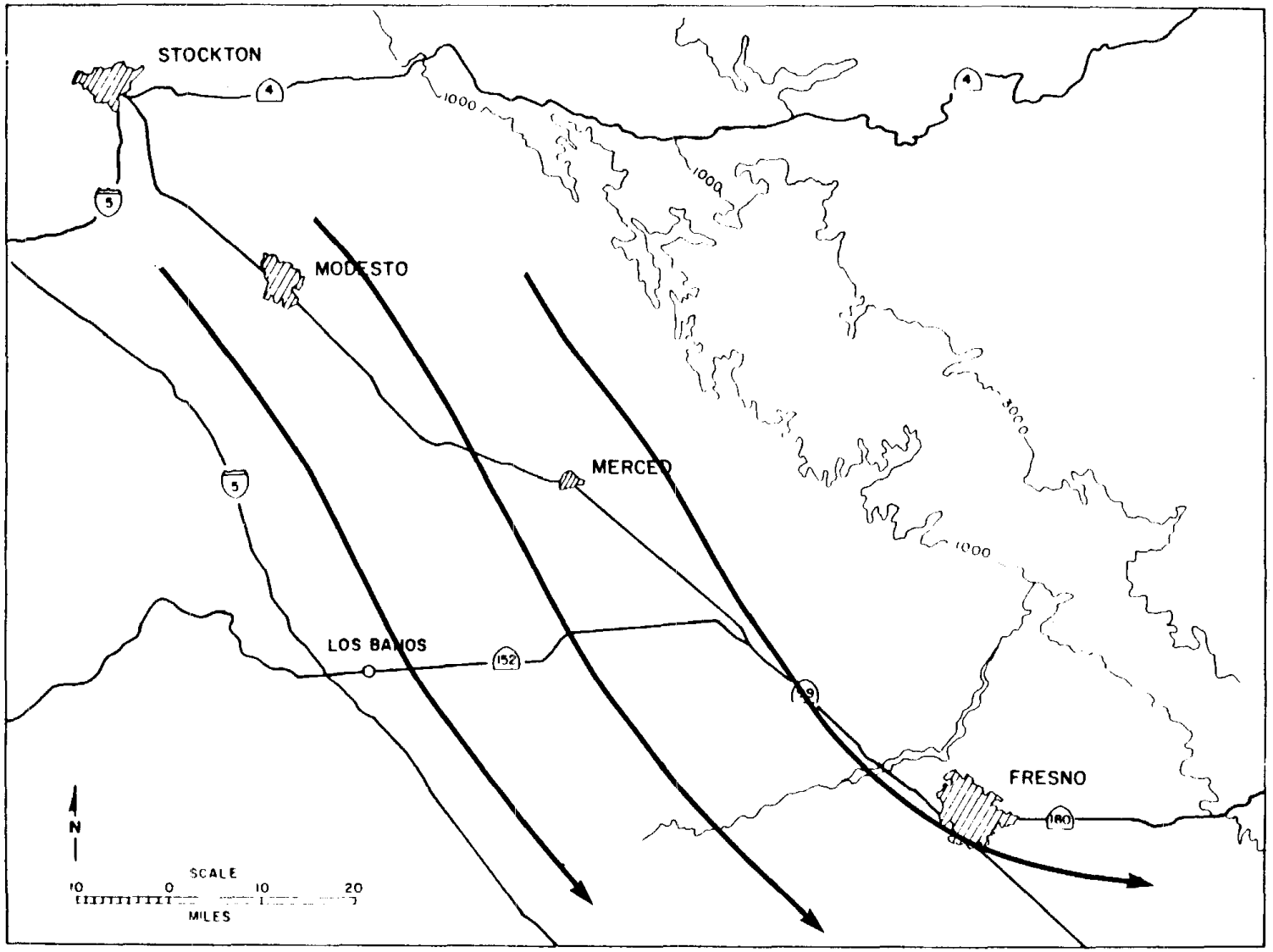


Figure 3.1.4 Surface Streamlines - 16 November 1978 (19 PST)

3.1.2 Air Quality

Surface Air Quality Summary

Pollutant concentrations throughout the valley were quite low on November 15, 1978. Figure 3.1.5 shows a map of maximum ozone concentrations at all stations in the valley for the day. Highest reading anywhere in the valley was 0.07 ppm at McKittrick.

Maximum hourly concentrations of CO, SO_2, and NO_x anywhere in the valley are shown in Table 3.1.4 together with maximum values measured at Reedley by the Rockwell International van.

Table 3.1.4

MAXIMUM HOURLY CONCENTRATIONS
NOVEMBER 15, 1978

Parameter	Location	Maximum Value (ppm)
SO_2	McKittrick	0.07
CO	Fresno (Olive)	18
NO_x	Fresno (Olive)	0.79
NO_x	Reedley	0.58

Particulate concentrations are indicated in a semi-qualitative manner by visibility observations. Table 3.1.5 shows the 1300 PST reported visibility at various airports in the valley for November 15, 1978. Causes of restricted visbility are given as H (Haze), F (Fog) or K (smoke).

Table 3.1.5

1300 PST VISIBILITIES (MILES)

Location	Visibility
Sacramento	3 HK
Stockton	2 FK
Modesto	3 FH
Crow's Landing	7
Merced	3 F
Fresno	4 H
Lemoore	3 H
Bakersfield	4 H

Early in the release period, 1000-ft winds at Chowchilla were southerly but turned to northerly (northwest to northeast) after 1500 PST. The northwesterly winds also appear at Fresno for the same period. Since this change occurred during the release period it is suggested that a portion of the tracer may have been transported to the north while some of the tracer released toward the end of the period could have been caught in the northerly flow and transported to the south. As indicated above the surface wind velocities at Chowchilla decreased substantially near the end of the release period and the bulk of the tracer would have experienced very low transport velocities during the night.

Mixing Heights

Mixing heights were determined from aircraft soundings by noting the top of the pollutant layer (usually determined from b_{scat} measurements). Table 3.1.3 gives the mixing heights for all soundings made on November 15.

The sounding at Athlone (41 NNW of Fresno) shows a multiple structure with one layer top at 510 m while the other top is at about 1100 m. The latter corresponds to the remaining soundings which did not show the more complex structure.

Table 3.1.3

AIRCRAFT MIXING HEIGHTS
NOVEMBER 15, 1978

Time (PST)	Location*	Mixing Height (agl) (m)
1451	10E Fresno Airport	840
1558	Fresno Airport	960
1611	Near I-5 (53 W FNO AP)	990
1644	Athlone (41 NNW FNO AP)	510
1722	Hidden Valley Airport (25 NNW FNO AP)	1020

*(distances in miles)

From this table it can be seen that visibilities throughout the valley were restricted, generally, to 2 to 4 miles, primarily due to haze and light fog.

Aircraft Sampling

The MRI airplane sampled in a pattern which traversed the valley between Chowchilla and Fresno. Spirals from near ground level to 5000 ft msl were flown at or near the traverse end points. All traverses were flown at 1500 ft msl within the surface mixing layer.

Figure 3.1.6 shows a map of the traverse paths and sounding locations for November 15. Table 3.1.6 gives a summary of the air quality data obtained by the aircraft during each traverse and spiral. Detailed vertical soundings of each parameter measured are shown in Figures 3.1.7 to 3.1.11.

Some spacial variability in the mixing layer was observed with no obvious pattern. Mixing was observed to 2700, 3500, 1900 and 3700 ft msl over Points 2, 5, 7 and 8, respectively. With the exception of the Fresno urban area, ozone was uniform throughout the sampling. Over Fresno (Points 3-4), a slight ozone deficit was observed. Moderate (in excess of 100 ppb) concentrations of NO_x were observed within the Fresno urban plume and near the surface on all spirals except over Point 8 (20 nm north of Fresno) where only low background concentrations were observed.

Maximum b_{scat} levels were observed in the Fresno vicinity with an otherwise relatively uniform horizontal distribution. Only light concentrations of SO_2 were observed. Elevated SO_2 layers were observed between Point 5 and I-5 (540 m msl) at Point 7 (390-480 m msl) and at Point 6 (990 m). The SO_2 layer at Point 7 showed high CN values, suggesting a fresh plume. The layer at Point 6 did not appear in the CN data and a well-aged plume is indicated. During the Point 7 sounding winds at the elevation of the SO_2 layer were from the northwest. The layer observed at Point 6 appeared to be imbedded in a flow from the southeast.

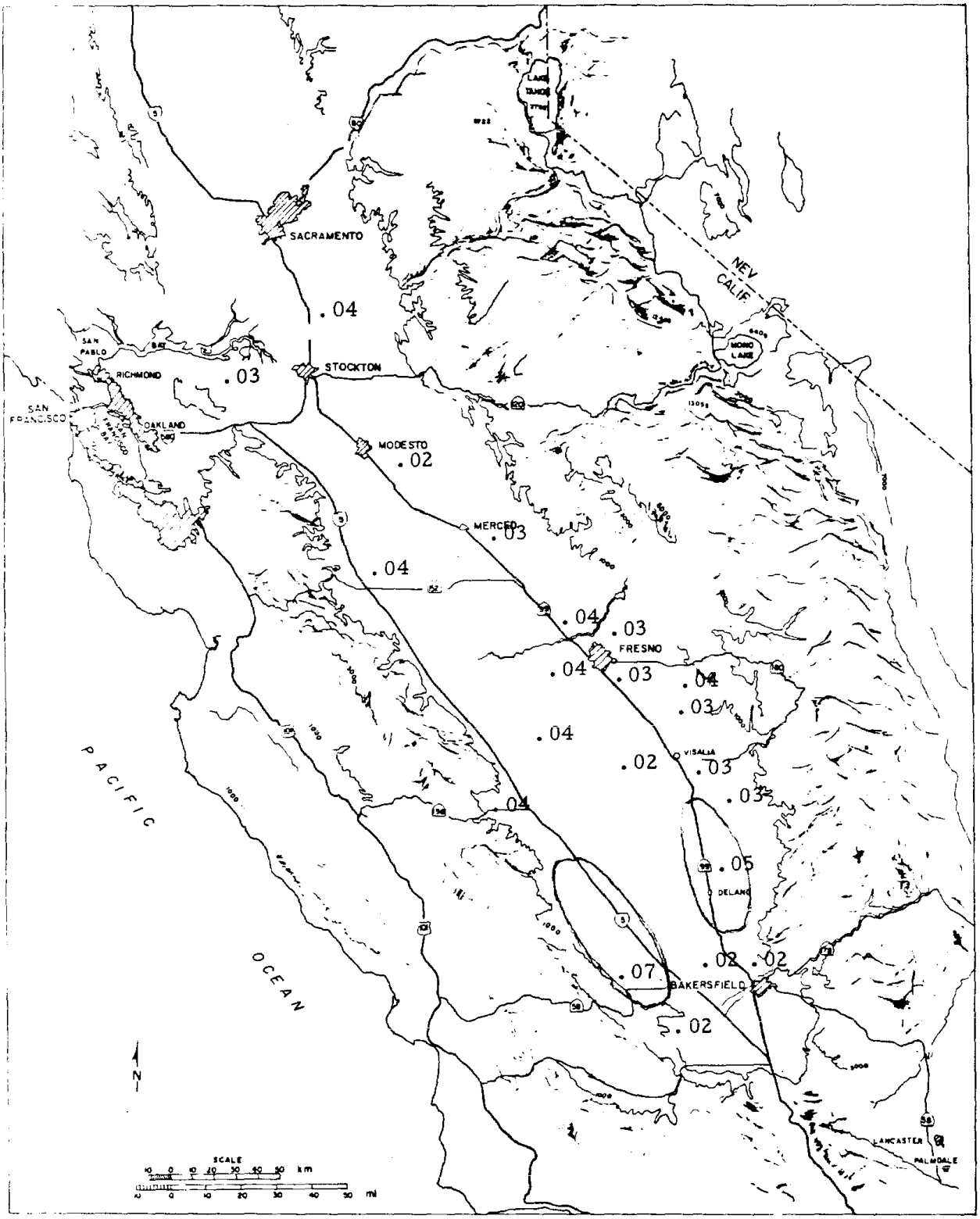


Figure 3.1.5 Maximum Hourly Ozone Concentrations (ppm) - November 15, 1978

Table 3.1.6

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 15, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1451	2	41	45	168	402	-	-	5	119	8	14
1510	3-4	40	46	307	602	17	46	13	132	5	19
1553	I5-I5	42	46	182	296	15	32	8	114	4	10
1622	6-7	40	47	240	344	12	21	9	18	8	18
1644	7	36	40	151	340	8	21	10	125	4	18
1705	7-8	36	40	289	362	5	25	11	20	5	14
1722	8	37	43	222	380	0	6	9	15	5	10
1734	8-1	38	49	343	538	-	-	17	46	5	11

*SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

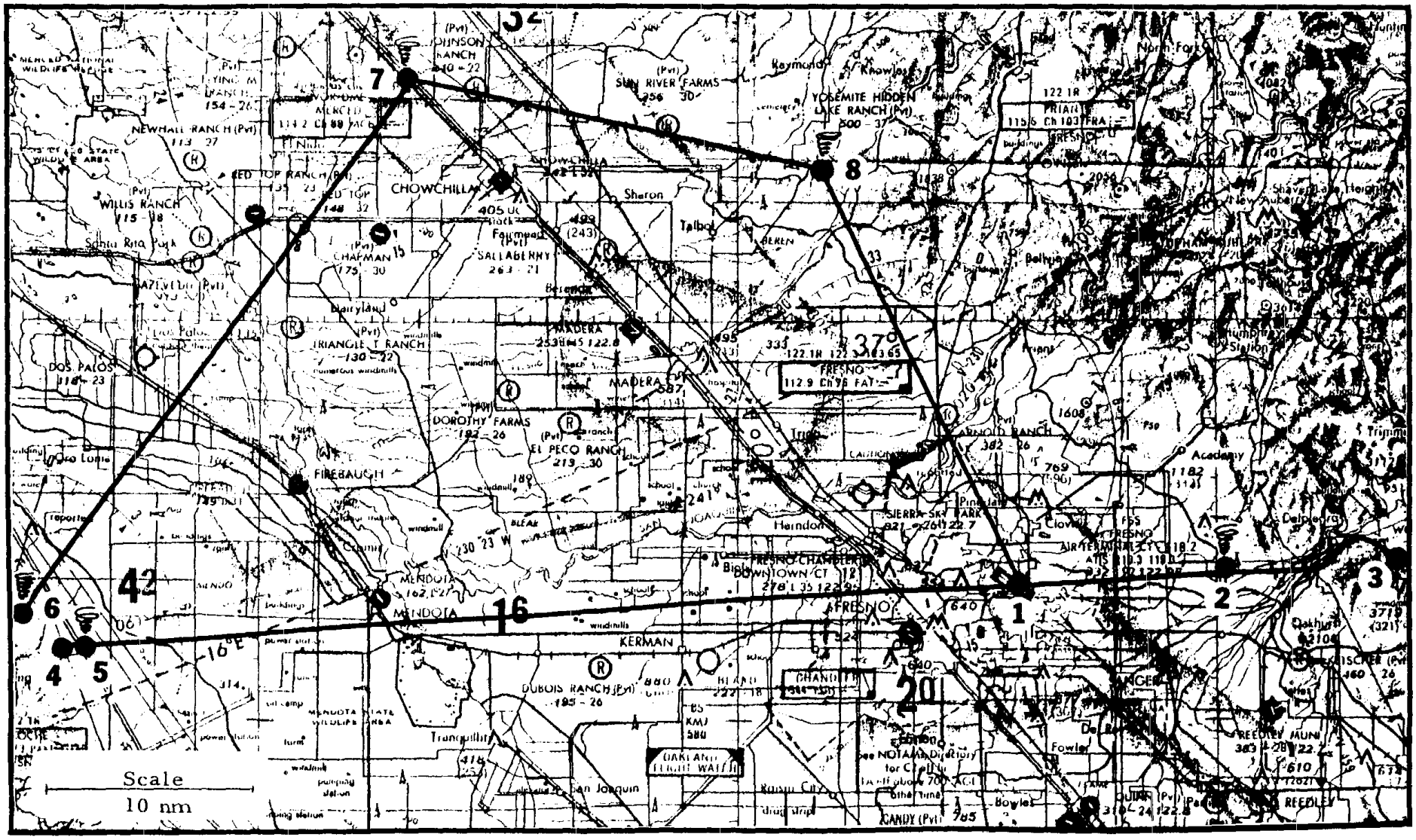
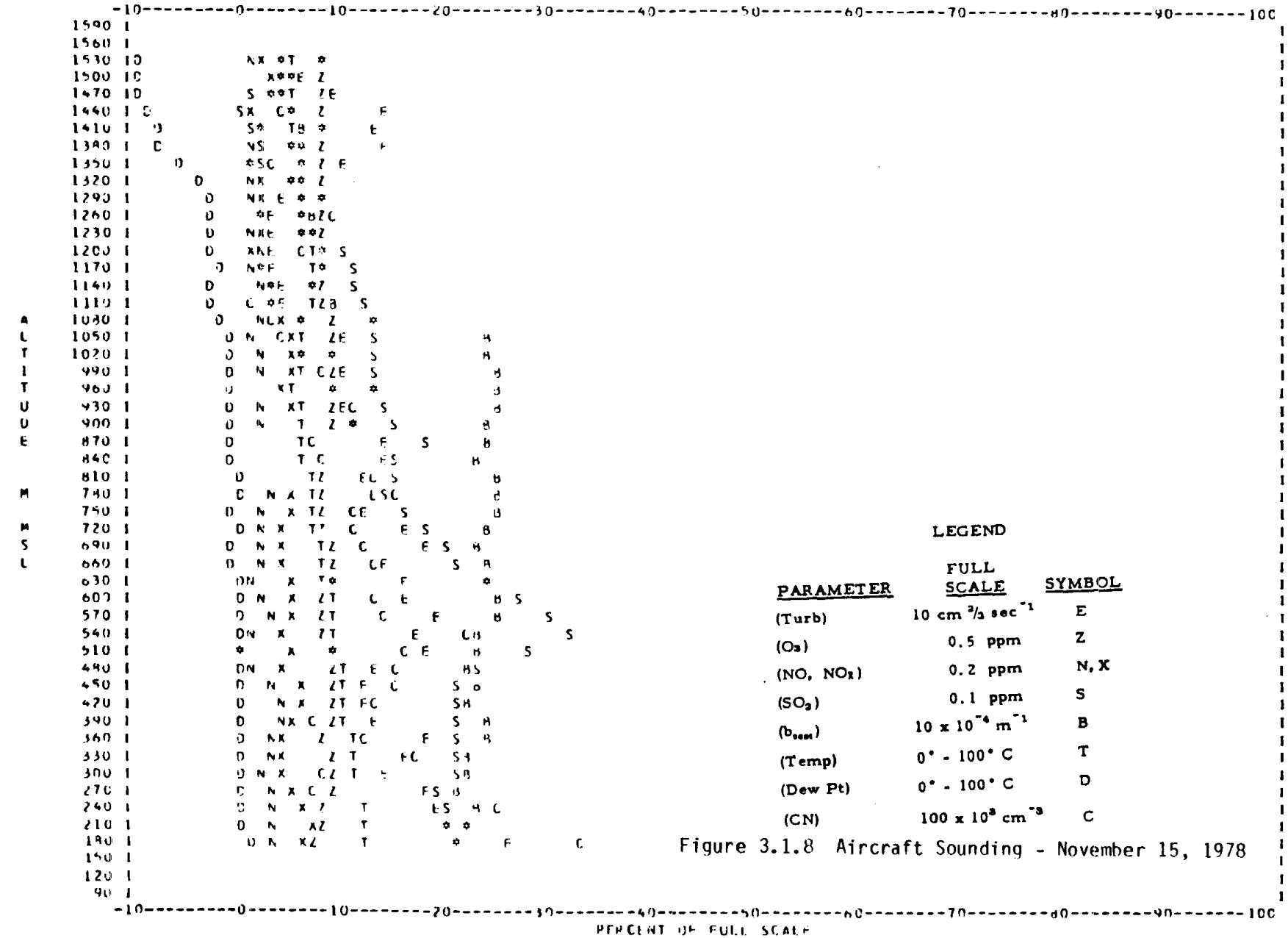

Scale
10 nm
1
2
3
4
5
6
7
8
16
20
42
FRESNO
CHOWCHILLA
MADERA
MENDOTA
KERMAN
FIREBAUGH
Sharon
Talbot
Herndon
Fowler
Academy
Tranquillity
Bowles
REEDLEY
SAMPLING ROUTES
15 November 1978

Figure 3.1.6

DATE: 11/15/78 ROUTE: POINT 5 TO POINT 1
CARTRIDGE/PASS: 1607 3
TIME: 15:58:40 TO 16: 7:50 MIN. GROUND ELEV.: 91 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Figure 3.1.8 Aircraft Sounding - November 15, 1978

DATE: 11/15/78 ROUTE: TVA POINT 2
CARTRIDGE/PASS: 1607 1
TIME: 14:51:12 TO 15: 1: 6 MIN. GROUND ELEV.: 91 M(MSL)

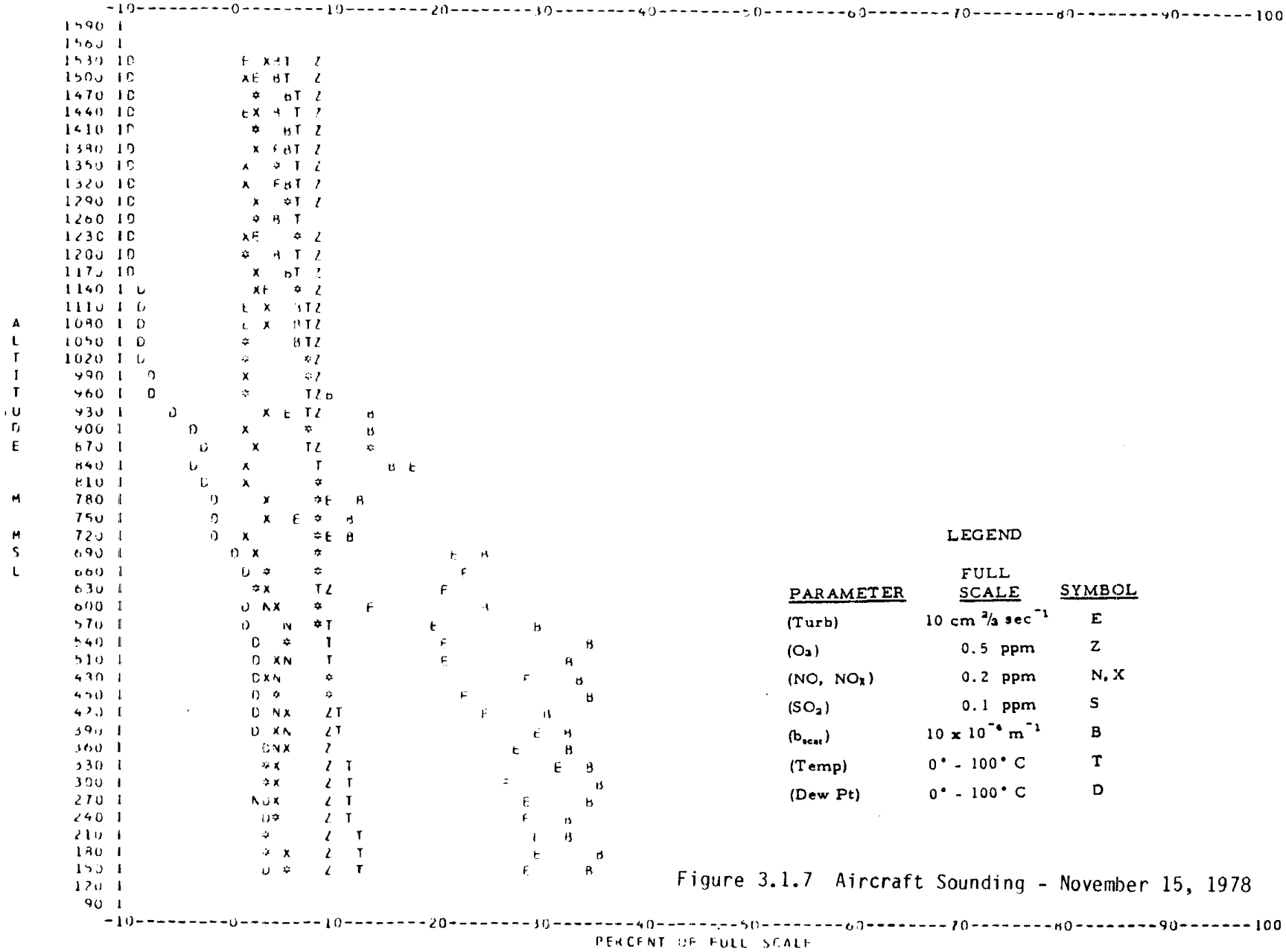
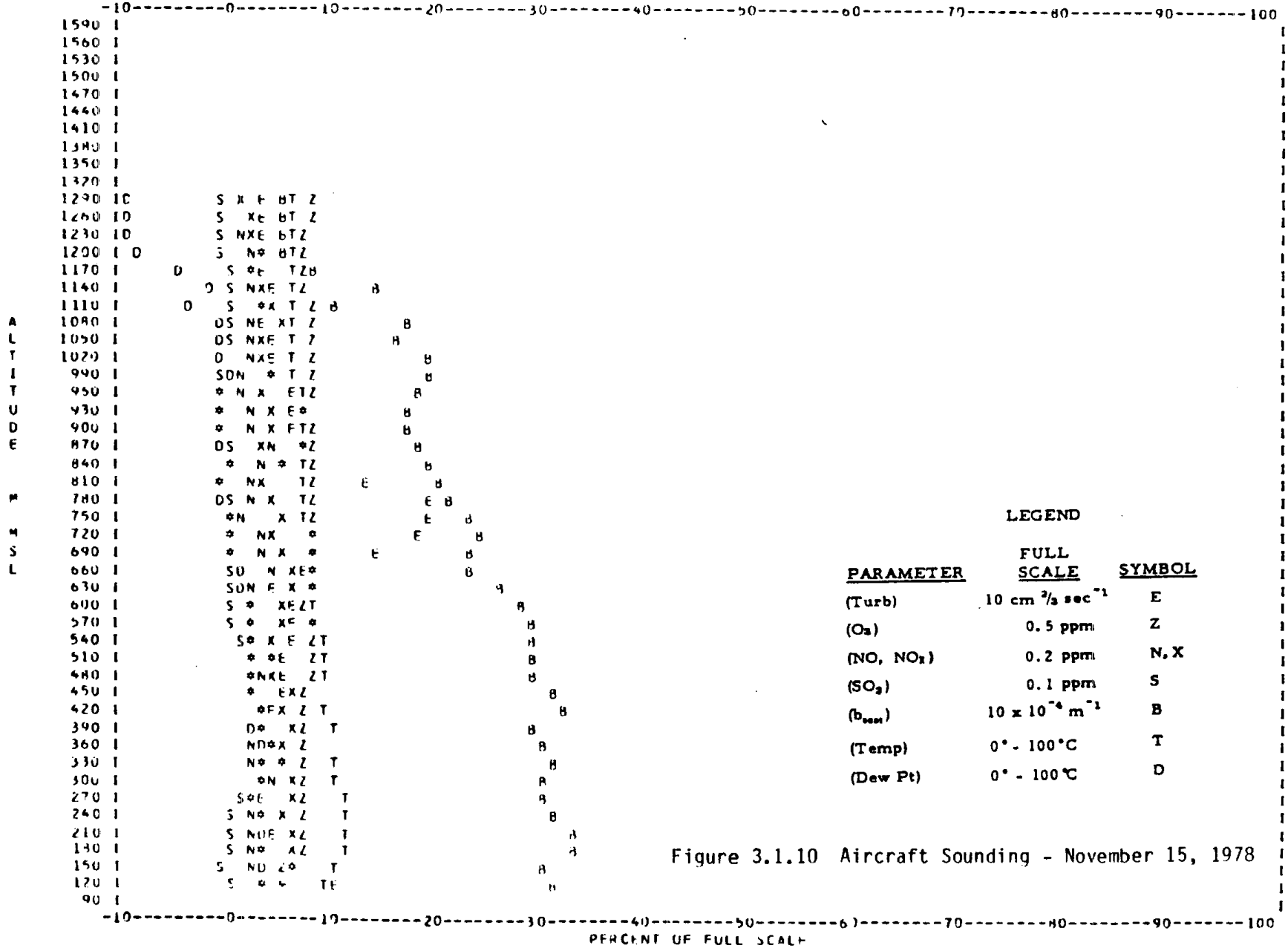


Figure 3.1.7 Aircraft Sounding - November 15, 1978

DATE: 11/15/78
CARTRIDGE/PASS: 1607 8
TIME: 17:22:39 TO 17:30:24

ROUTE: [illegible] POINT 8
MIN. GROUND ELEV.: 91 M(MSL)



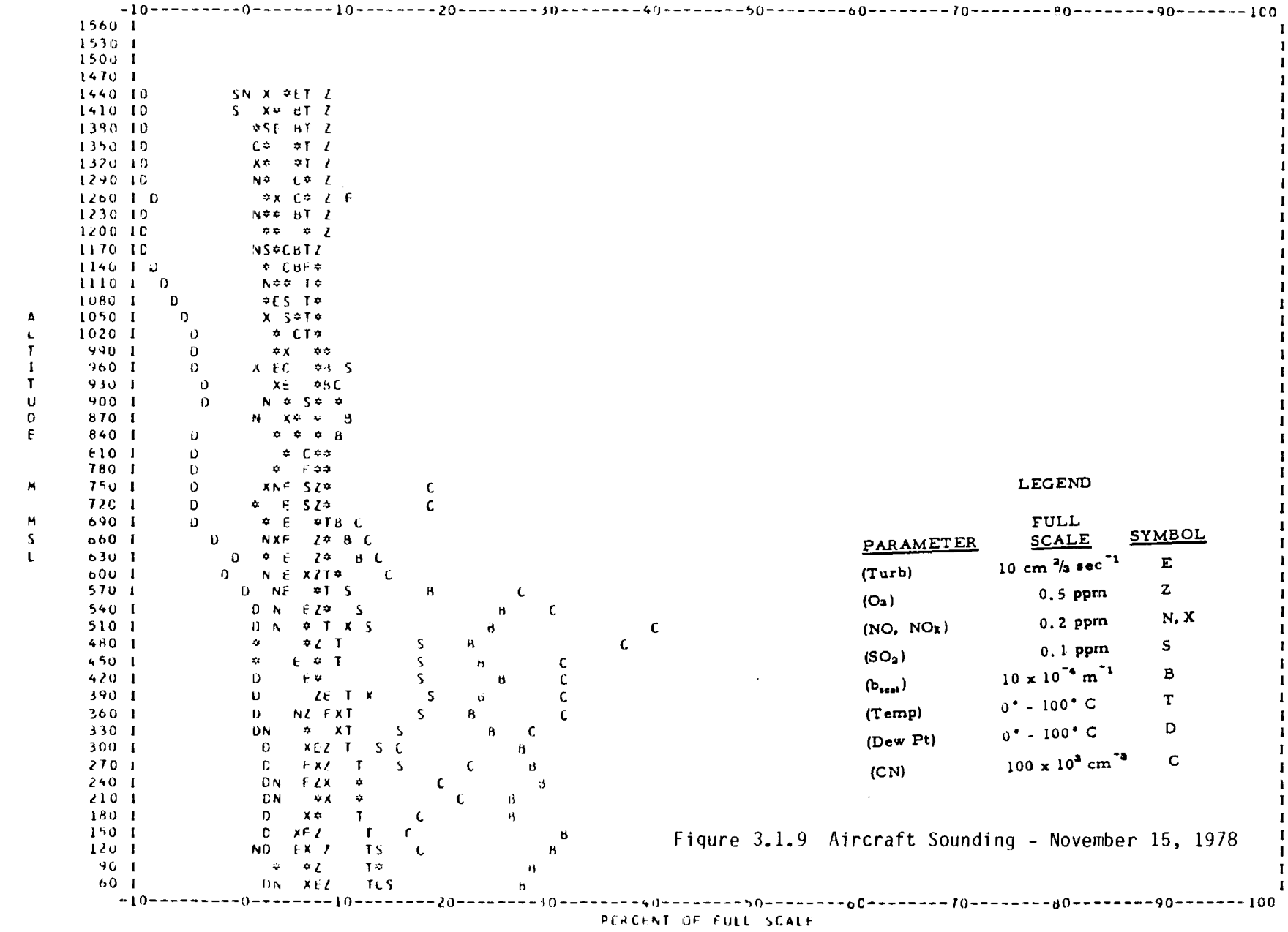
LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_2)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100°C	T
(Dew Pt)	0° - 100°C	D

Figure 3.1.10 Aircraft Sounding - November 15, 1978

DATE: 11/15/78
CARTRIDGE/PASS: 160/ 6
TIME: 16:44:34 TO 16:53:59

ROUTE: [illegible] POINT 7 (CONTINUED)
MIN. GROUND ELEV.: 60 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Figure 3.1.9 Aircraft Sounding - November 15, 1978

3.1.3 Tracer Test 1

Release Location: Chowchilla, Madera County
Time and Date: 1100-1600 PST, 11/15/78
Amount: 98 pounds of SF_6 per hour
Release conducted during light southerly winds

Initial transport northward

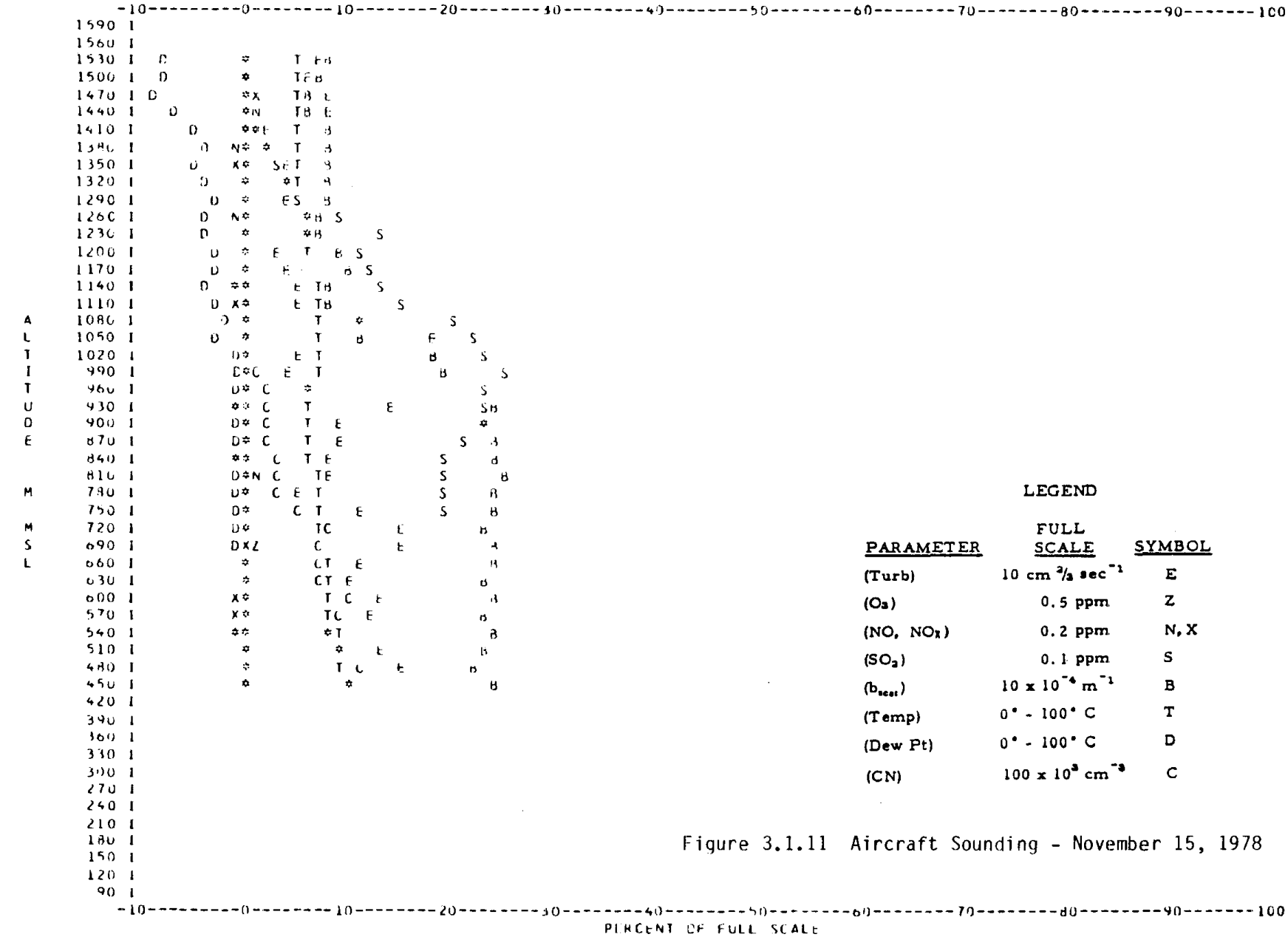
SF_6 was first detected around 1800 PST during Automobile Traverse 1-2. SF_6 levels of about 80-85 ppt were detected near Planada, about 15 miles north of the release point during this traverse. About 2200 PST, SF_6 levels as high as 250 ppt (375 ppt/lb-mole of SF_6 released/hr) were detected along Highway 99, north of the release site. For a short period of time near the end of the release, the winds at the surface and aloft were from the north. This was reflected in the detection of SF_6 just south of Chowchilla. Most of the SF_6 was thus apparently transported north of the release site but the generally light and somewhat variable winds also led to dispersal of the SF_6 with little net transport. None of the tracer was detected farther than about 15 miles from the release site on the day of the release.

Net transport southward during night and following morning

On the morning following the SF_6 release some of the tracer was detected during Traverse 4-1 near Merced, north of the release site. A maximum SF_6 level of 22 ppt was detected during this traverse. The bulk of the tracer however, was apparently south of the release site. Between 1100 and 1200 PST on 11/16/78, 65 ppt of SF_6 was detected at the Fresno hourly-averaged sampler. All of the hourly-averaged data is presented in Figure 3.1.12 and a map of the locations is presented in Figure 3.1.13. Prior to this time essentially no SF_6 was detected at Fresno. The Fresno measurement was verified, however, by the simultaneous measurements of 21 and 45 ppt SF_6 at the neighboring sampling sites of Clovis and Easton, respectively. The detection of SF_6 at these sites apparently reflected the development of a northwesterly flow (as measured at the surface at Chowchilla). The arrival time of SF_6 at Fresno corresponded to a net

CDEPLT VER 01 MOD 03 18-APR-80 33:41:59 PAGE 7

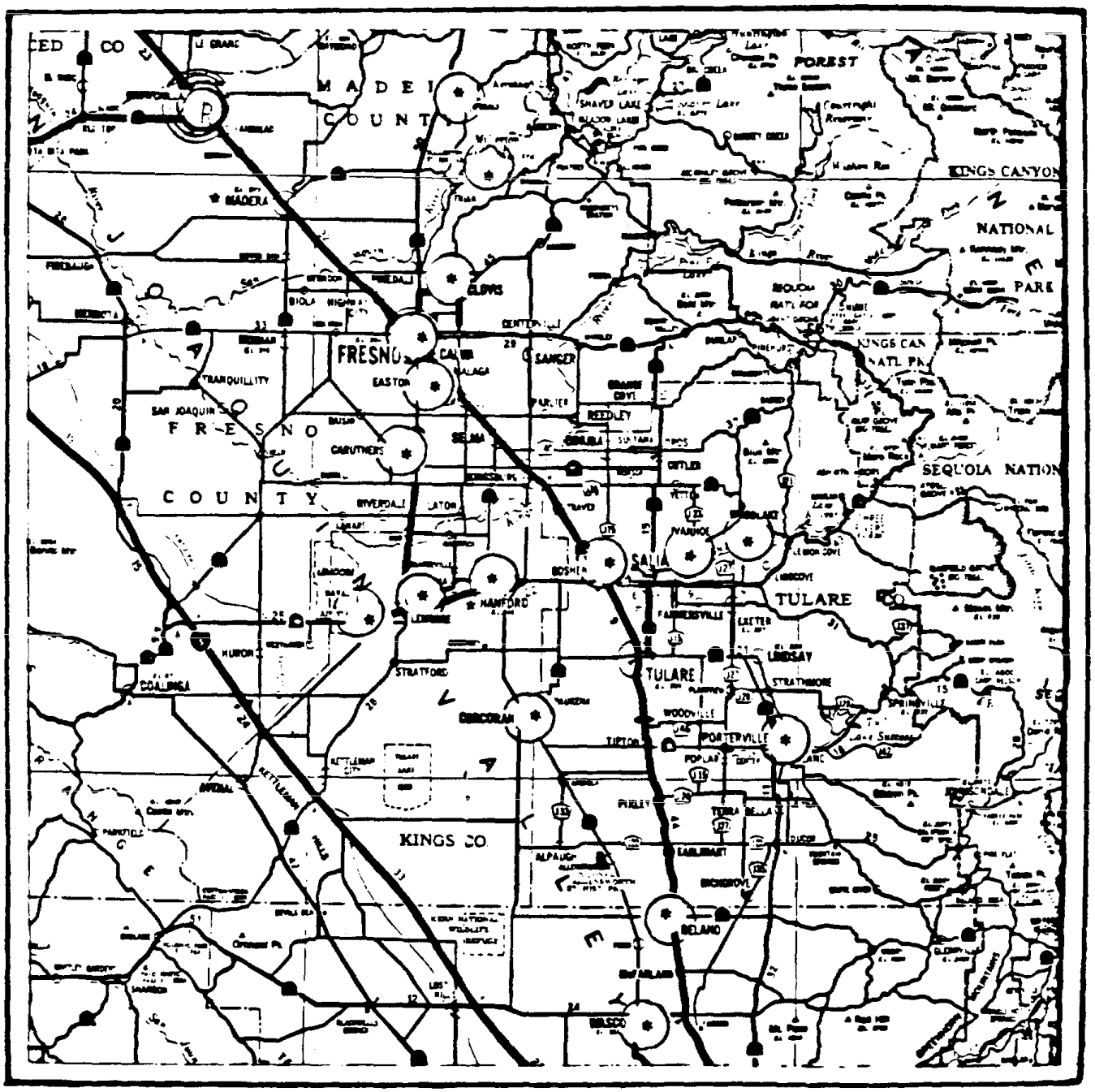
DAT : 11/15/78 ROUTE: OVER POINT 6
CARTRIDGE/PASS: 1607 4
TIME: 16:11:28 TO 16:21: 1 MIN. GROUND ELEV.: 91 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

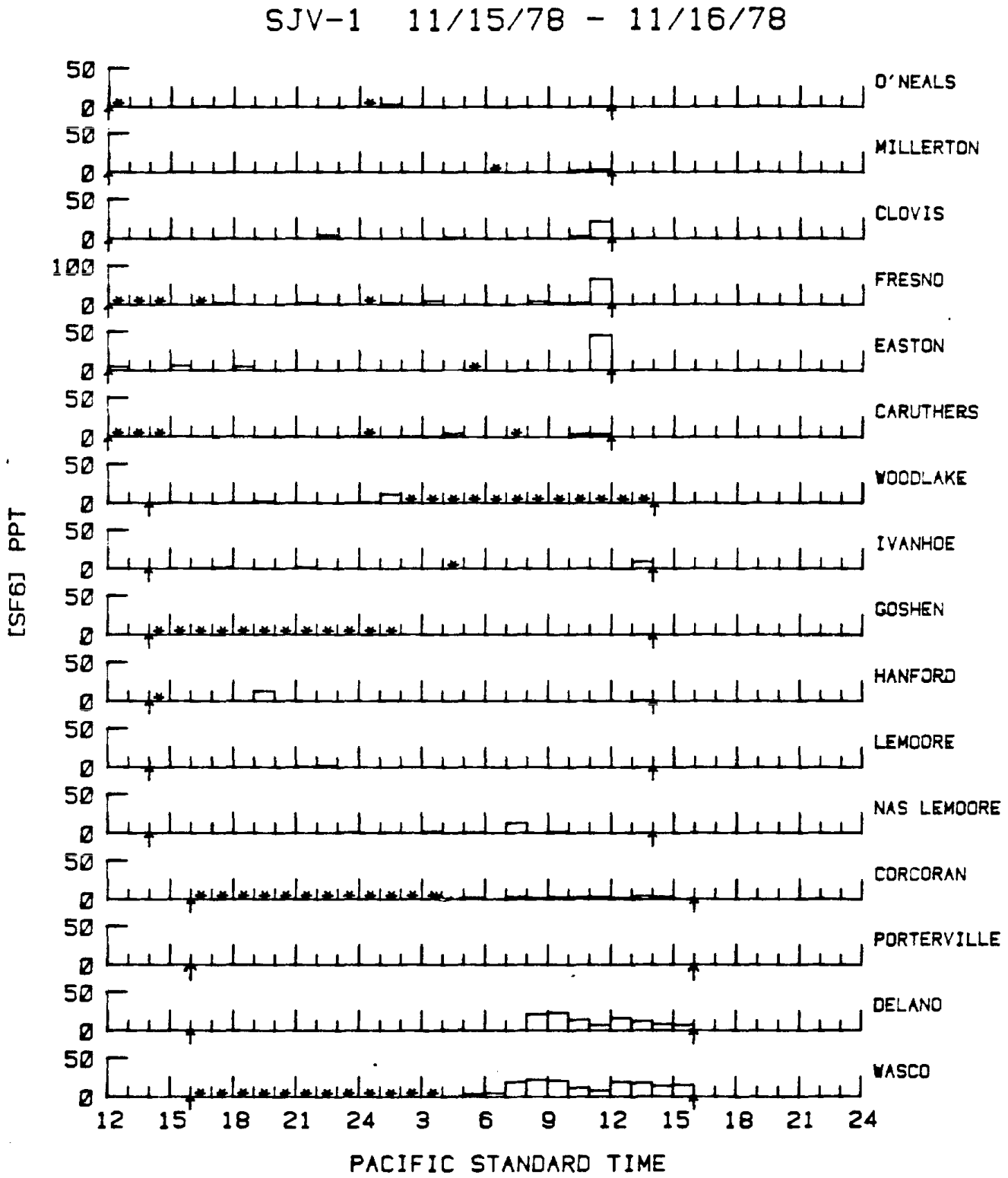
Figure 3.1.11 Aircraft Sounding - November 15, 1978



INDICATES SAMPLER LOCATIONS

R IS THE RELEASE SITE

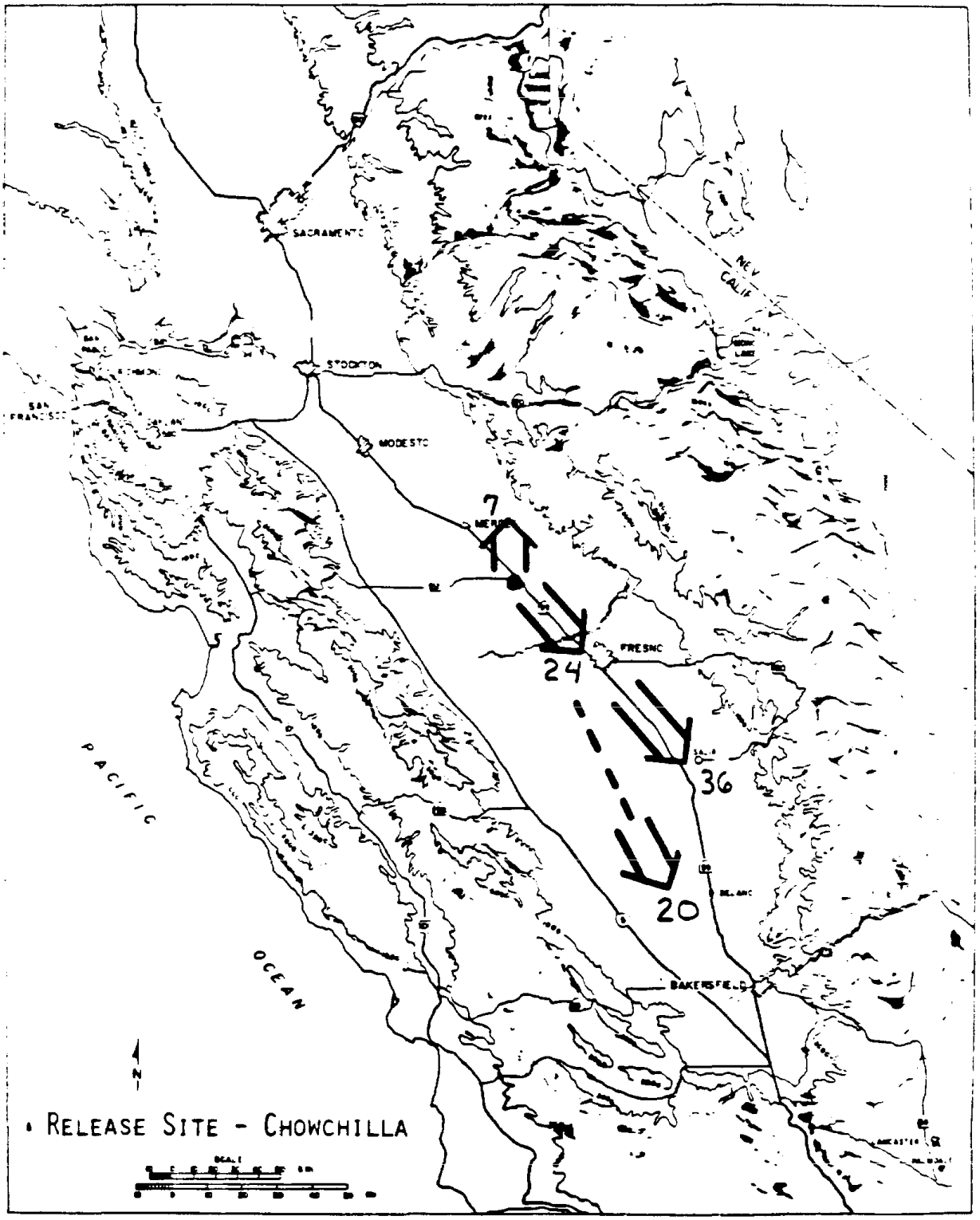
Figure 3.1.13



RELEASE LOCATION: 491 LBS SF6 AT CHOWCHILLA
RELEASE TIME: 1100-1600 PST, 11/15/78

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.1.12



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (1100 PST, 11/15/78)
- - - UNCEPTAIN TRANSPORT PATH

Figure 3.1.14

transport speed of about 1.5 mph from the Chowchilla release site. SF_6 concentrations as high as 90 ppt were detected by automobile traverses near Fresno between 1800 and 2300 PST, 11/16/78. During Traverse 4-3 an average SF_6 concentration of about 50 ppt was detected between Fresno and Visalia, 35 miles to the south. About 80 percent of the SF_6 originally released can be accounted for during this traverse assuming that the SF_6 covered a rectangular area about 10 miles wide (as suggested by the automobile traverse data) and by assuming that the maximum mixing height on 11/16/78 was about 2000 ft. Though subject to potentially large uncertainties this calculation suggests that the majority of the tracer released on 11/15/78 remained within the San Joaquin Valley (and within 70 miles of the release site), by the following evening (11/16/78).

Although most of the tracer was apparently near Fresno during the day after the release, hourly-averaged SF_6 concentrations as high as 20-25 ppt were detected in both Delano and Wasco between 0700 and 1600 PST, 11/16/78. These sites lie approximately 110 miles south of the release point (Chowchilla). This suggests a mean transport speed in excess of 5 mph for the SF_6 detected at these sites. This transport was apparently due to the winds aloft but this conclusion could not be verified because of a sparcity of wind data during the night of 11/15 and early morning of 11/16.

Summary

During this test, SF_6 was released from Chowchilla in the northeastern San Joaquin Valley, under generally light and variable wind conditions. This limited the net transport of the tracer. Figure 3.1.14 displays an overview of the transport path of the tracer during this test. The majority of the tracer apparently remained within 70 miles of the release site more than 24 hours after the end of the release. The net transport speed of most of the tracer was between 1 and 3 mph towards the south over the course of the test period. It should be noted that the SF_6 was transported towards the south by the end of the day following the release (11/16/78) even though southerly winds seemed to prevail at the surface at the release site (i.e., a southerly wind was detected more often than a northerly wind at the release site, at least between the start of the release on 11/15/78 and noon on 11/16/78).

3.2 Test 2 18-19 November 1978 - Fresno Release (1200-1700 PST)

3.2.1 Meteorology

General

At the onset of this test, Central California was situated in a region between two weak high pressure areas, one located over Utah and the other about four hundred miles west of San Francisco (Figure 3.2.1). Consequently, pressure gradients were weak and only light synoptic scale flows existed. By the following morning, both high pressure areas were shifting south in response to a storm system entering the Pacific Northwest. Nevertheless, the pressure gradients in the central and southern portions of California remained weak. The warming trend at 850 mb, which had begun several days prior, peaked on the 18th at the 5-year average. At Fresno, fog obscured the sky and restricted visibilities to one mile until noon on the 18th. Clear skies persisted the remainder of the day although visibilities remained restricted to four miles in haze. Only light fog occurred on the following day but visibilities, although increasing slightly, were restricted again by haze. Near normal November maximum surface temperatures were recorded at Fresno during the test period.

Transport Winds

Figures 3.2.2 to 3.2.4 show surface streamline maps in the southern half of the valley for several periods during and after the release. During the latter part of the release period, winds at Fresno were southerly, resulting in transport of the tracer to the north of the city. During the evening an easterly drainage flow dominated the Fresno area as shown in Figure 3.2.3. This was replaced by a northwesterly flow in the morning as indicated in Figure 3.2.4.

Additional details on surface wind flow in the Fresno area are shown in Table 3.2.1. The southerly flow at the Fresno airport lasted from 1600-1800 PST and was replaced by the easterly flow from 1900 PST through 0200 PST on November 19. Thereafter the winds at the airport were from the northwest.

Some of the SF_6 released at Chowchilla was detected at Delano and Wasco in the southern San Joaquin Valley on the morning of 11/16/78. While this SF_6 was apparently not a large portion of that originally released, it does suggest that a mechanism exists for rapid transport of air pollutants toward the southern end of the valley even during generally stagnant conditions. At the present time, it appears that only the winds aloft could transport the tracer towards the south at the required speed (in excess of 5 mph).

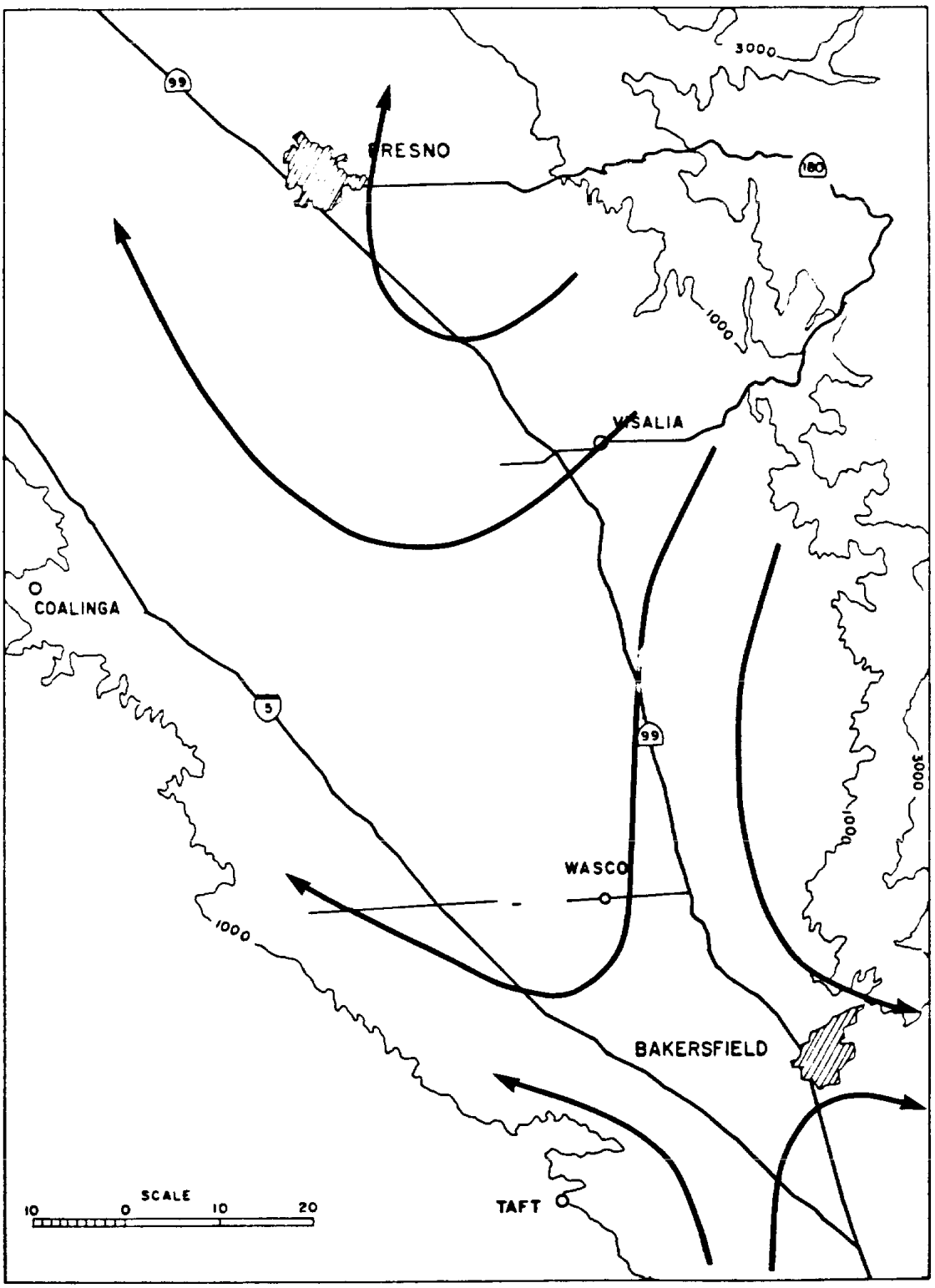


Figure 3.2.2 Surface Streamlines - 18 November 1978 (16 PST)

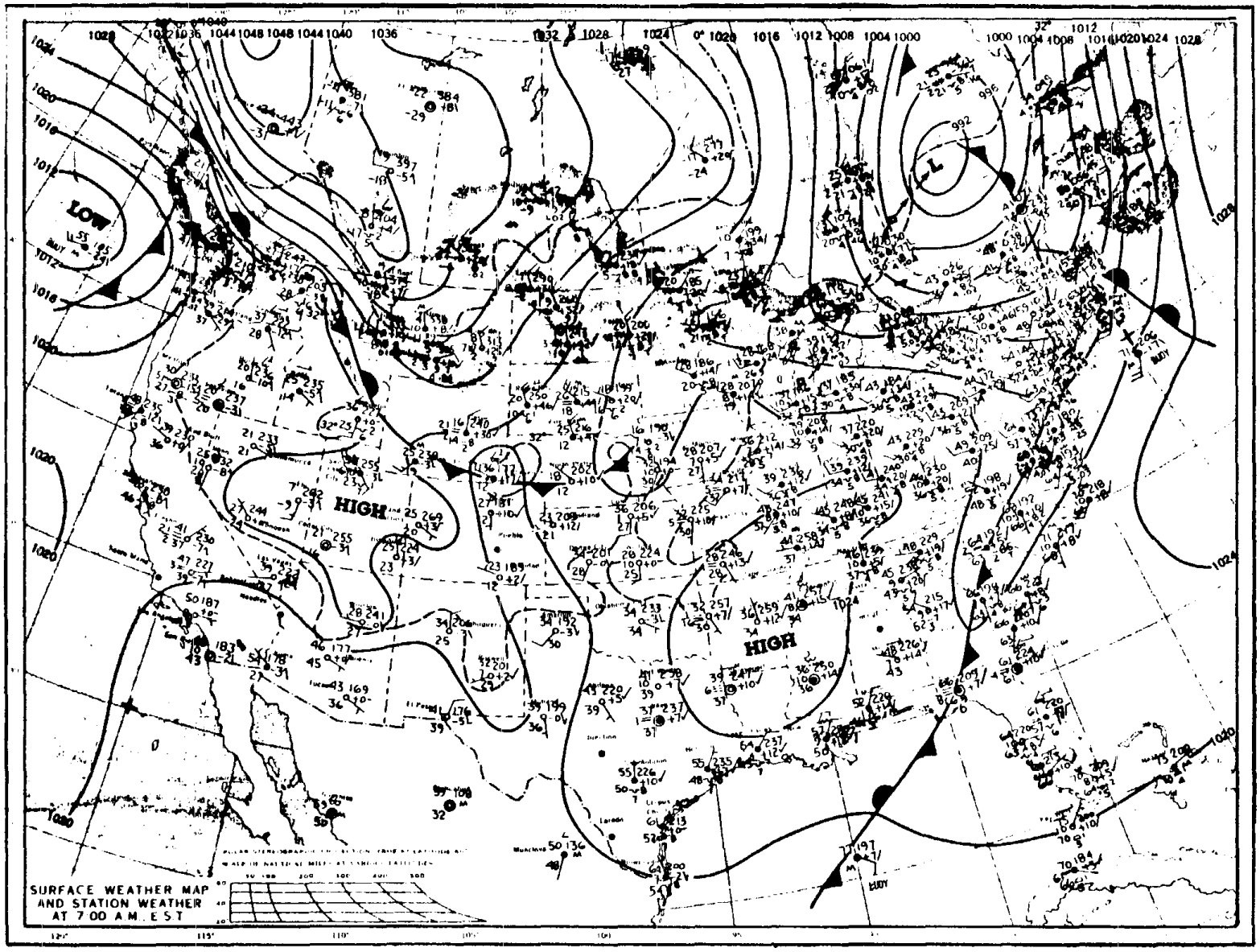


Figure 3.2.1 Surface Weather Map - November 18, 1978

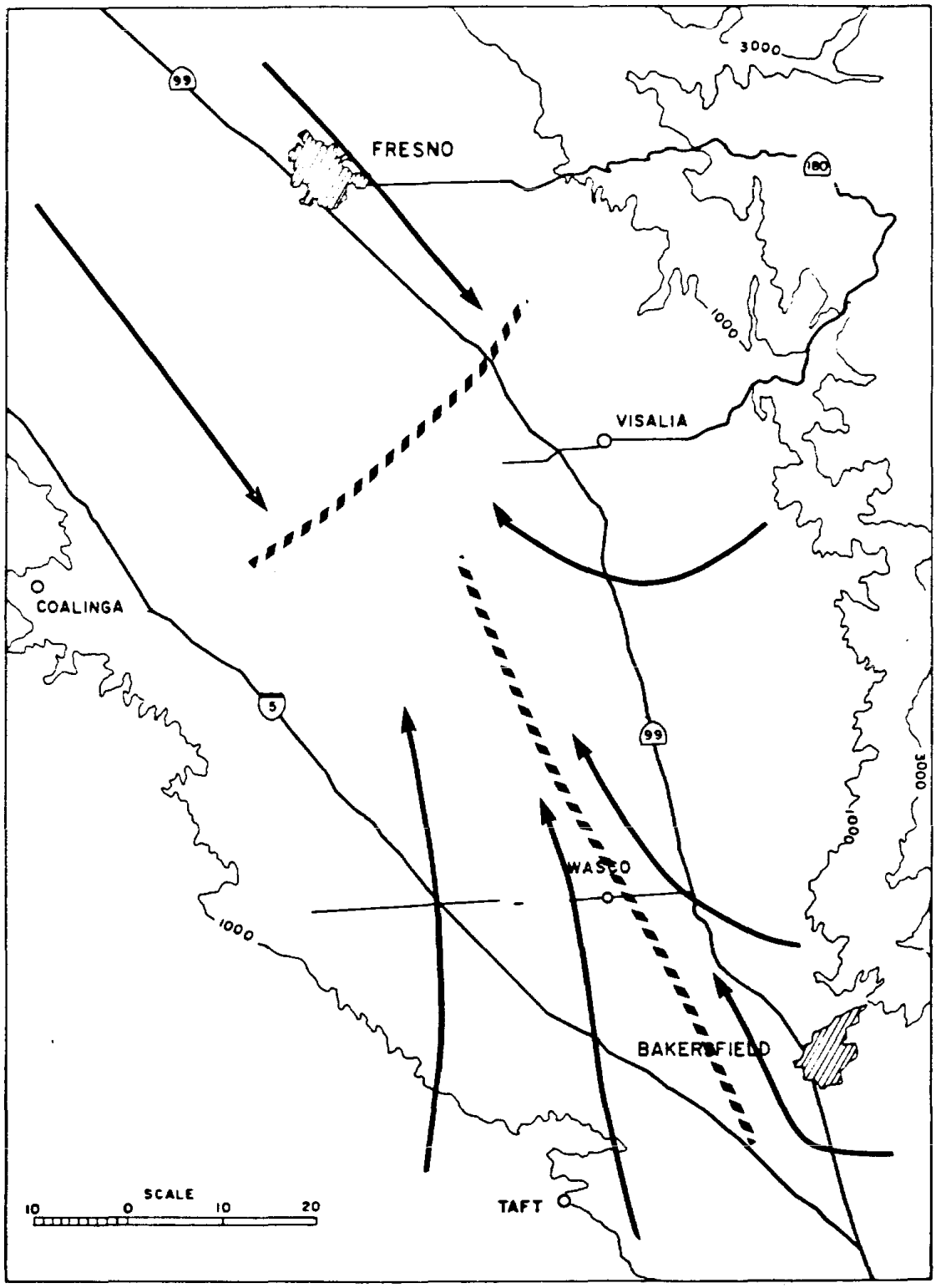


Figure 3.2.4 Surface Streamlines - 19 November 1978 (07 PST)

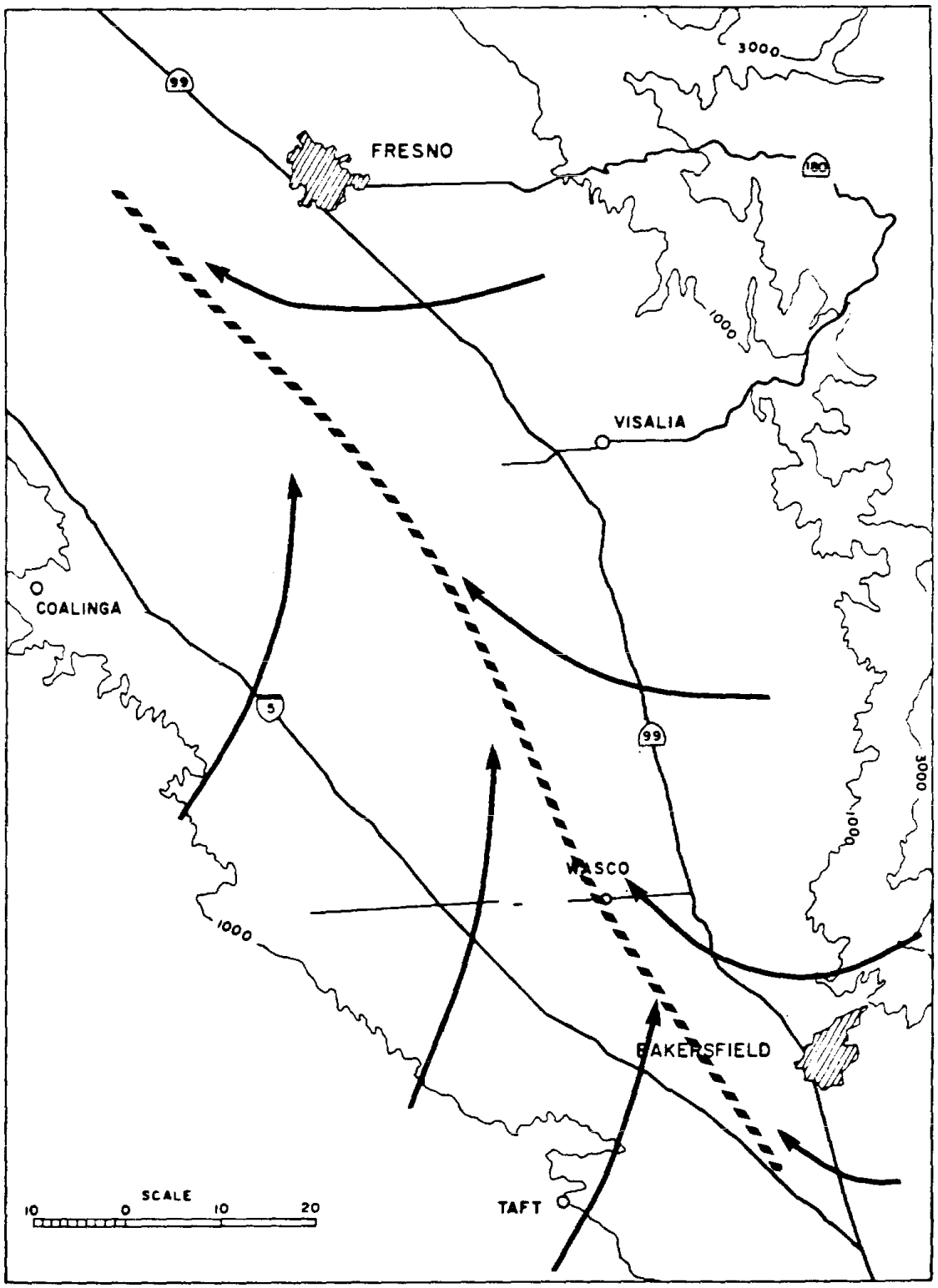


Figure 3.2.3 Surface Streamlines - 19 November 1978 (01 PST)

These data suggest a shallow (less than 1000 ft deep) layer moving in response to an easterly flow during the night and a northwesterly flow in the early morning but decoupled from the flow at 1000 ft. Much of the tracer released in the late afternoon (after the low-level air had started to stabilize) must have been trapped within this shallow layer.

Mixing Heights

Mixing heights were obtained from aircraft soundings made on November 17 and 18. These are shown in Table 3.2.3. Heights ranged between 480 and 600 m (above ground level) on both days, indicating little change in the overall synoptic conditions during the two-day period. This conforms to the peak in the 850 mb temperature curve which occurred on November 18.

Table 3.2.3

AIRCRAFT MIXING HEIGHTS

Time (PST)	Location*	Mixing Height (agl) (m)
	November 17, 1978	
0927	over Hwy 99 (4 SW FNO AP)	480
1034	near Hwy 99 (9 NW FNO AP)	480
1229	over Hwy 99 (4 SW FNO AP)	600
	November 18, 1978	
1424	8 NNW FNO AP	540

* Distances in miles

3.2.2 Air Quality

Surface Air Quality

Maximum ozone concentrations in the valley were somewhat higher than on November 15, reflecting the influence of the warmer 850 mb temperatures. Highest-values (0.07 ppm) within the valley were observed at McKittrick and Lost Hills. A considerable part of the valley experienced maximum concentrations of 0.05 ppm or more. Figure 3.2.5 shows a map of the maximum ozone concentrations throughout the valley on November 18.

Table 3.2.1

SURFACE WINDS - FRESNO AIRPORT
NOVEMBER 18-19, 1978

Time (PST)	Wind	Time (PST)	Wind
1200	110°/2.1 m/s	2200	090°/2.6 m/s
1300	070 /2.1	2300	060 /3.1
1400	080 /2.1	0000	070 /2.6
1500	110 /1.5	0100	070 /2.6
1600	210 /1.5	0200	070 /2.6
1700	180 /1.5	0300	300 /1.5
1800	210 /1.5	0400	340 /1.5
1900	090 /1.5	0500	350 /1.5
2000	050 /1.5	0600	Calm
2100	090 /2.6	0700	310 /2.6

1000-foot winds for November 18 and early November 19 are shown in Table 3.2.2 for Fresno, Reedley and Pinedale. Southerly winds prevailed at all stations beginning at 1400 PST on November 18 although velocities during the evening were quite low. It is to be noted that the easterly drainage flow so dominant in the surface winds (Table 3.2.1) does not appear at the 1000-foot level. This indicates the shallow nature of the drainage flow. In a similar vein, the morning northwesterly flow at the surface is not reflected in the 0500 PST 1000-foot wind observation at Fresno.

Table 3.2.2

1000-FOOT WINDS

Date	Time (PST)	Fresno Wind	Reedley Wind	Pinedale Wind
11-18	11	169°/0.8 m/s		
	12		29°/0.3 m/s	
	13	320 /0.8	50 /0.3	
	14		187 /0.7	
	15	178 /1.8		184°/0.8 m/s
	16			153 /1.0
	17	224 /0.7		199 /0.6
	19	221 /0.2		
11-19	05	170 /2.7		

Table 3.2.4 gives the maximum concentrations of other parameters as observed on November 18:

Table 3.2.4

MAXIMUM POLLUTANT CONCENTRATIONS
NOVEMBER 18, 1978

Location	CO (ppm)	SO_2 (ppm)	NO_x (ppm)
Fresno-Olive	16		
Bakersfield	16		
McKittrick		0.07	
Bakersfield			0.90
Reedley			0.66
Lost Hills		0.04	0.32

Visibilities throughout the valley at 1300 PST are shown in Table 3.2.5.

Table 3.2.5

1300 PST VISIBILITIES
NOVEMBER 18, 1978

Station	Visibility (miles)
Sacramento	2 FH
Stockton	3 HK
Modesto	3 H
Merced	2-1/4 H
Fresno	2-1/2 H
Lemoore	3 H
Visalia	4 H
Bakersfield	1-3/4 HK

These visibilities represent slightly lower values than were observed on November 15. Most of the restriction was described as resulting from haze. There was no fog observed except at Sacramento.

Aircraft Sampling - 17 November 1978

This flight was intended to measure the vertical and horizontal extent and distribution in the undisturbed Fresno urban plume. This necessitated a morning flight when decoupling with the synoptic flow was present and when weak local thermal gradients existed. The flight plan consisted of the following key elements:

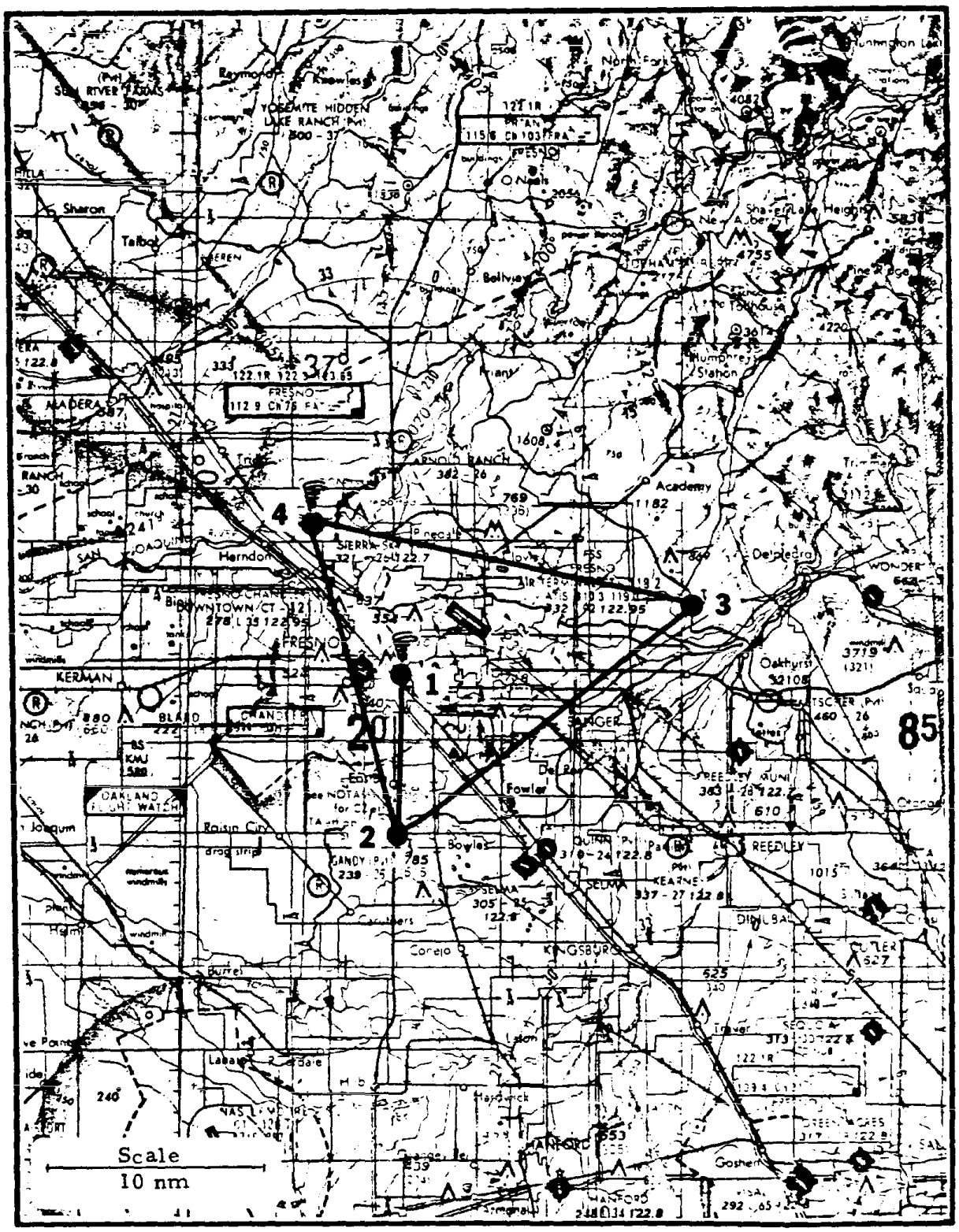
- Spirals over the downtown area at the start and end of sampling to define any temporal changes.
- Traverse south within polluted urban air away from downtown until background air was encountered, then
- Traverse northeast, intersecting the urban air until background levels east of Fresno were encountered, and
- Traverse west in a similar manner to a point NW of Fresno and then a traverse back to the start of the pattern such that a triangle was formed roughly defining the horizontal extent of the urban plume.
- Repeat the triangular pattern to observe temporal change.

Figure 3.2.6 shows the flight pattern followed on November 17. Table 3.2.6 gives the maximum concentrations encountered on each of the segments of the flight pattern.

Visibilities were restricted by haze and fog which resulted in off-scale b_{scat} levels and precluded valid maximum nephelometer data in some areas.

Detailed soundings for November 17 are included as Figures 3.2.7 to 3.2.9. Principal comments on the observations are:

- Mixing depths increased from 490 to 600 m - m agl during the sampling period (0927-1303 PST). A lower level mixed layer about 120 m deep was present at 0927, representing the early morning surface mixing. Carry-over from the previous day existed to 540 m or more. By 1229 PST the surface mixed layer had reached to approximately the top of the carry-over layer.
- Maximum NO_x level observed within the urban plume was 106 ppb.



SAMPLING ROUTES 17 November 1978

Figure 3.2.6

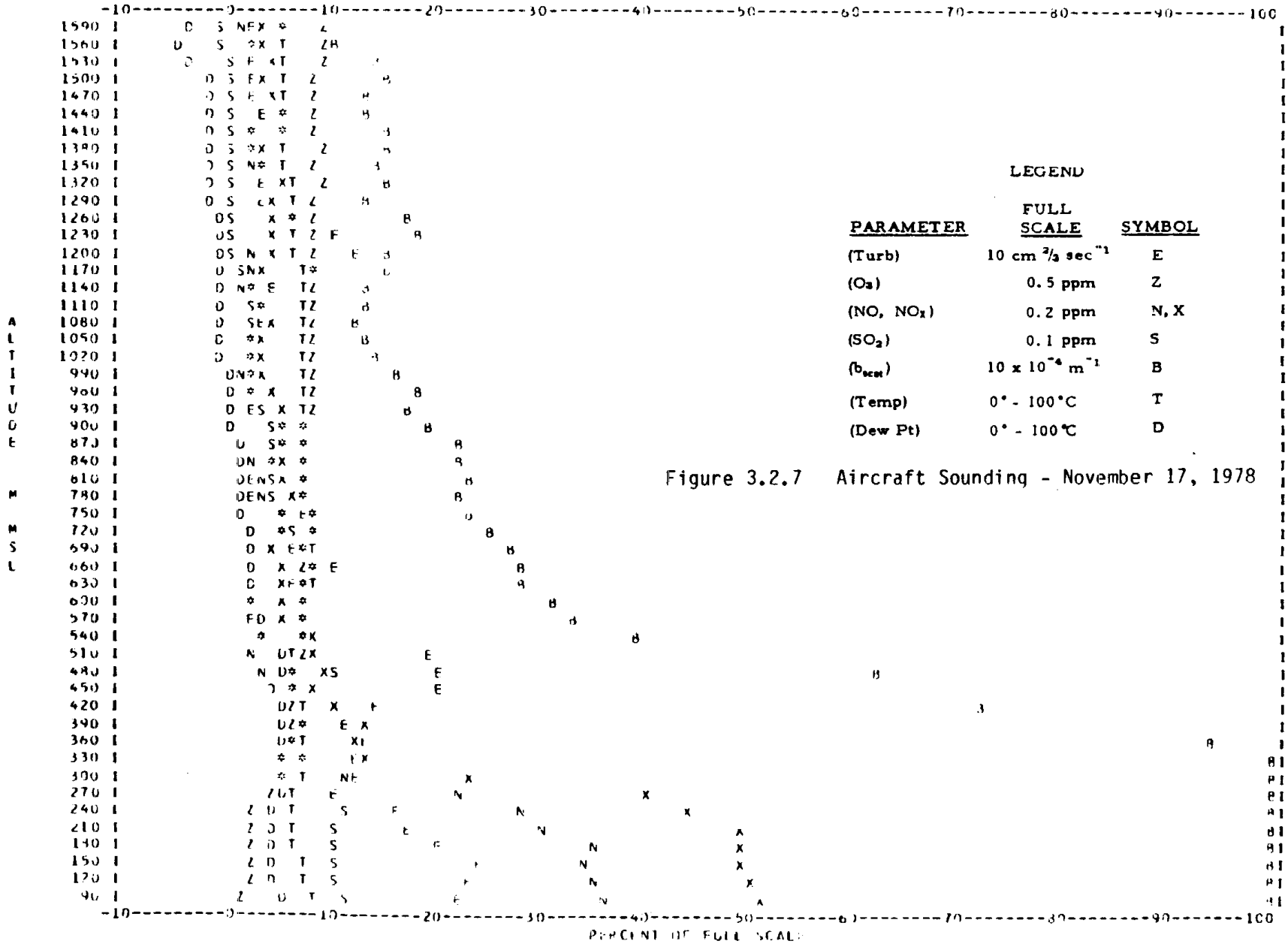
Table 3.2.6

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 17, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
0927	1	35	46	420	1830	4	15	20	106	15	75
1008	2-3	34	45	1195	1860	7	8	29	54	11	30
1022	3-4	40	51	666	1630	10	13	20	88	12	24
1034	4	40	55	489	1460	4	8	14	38	8	24
1058	4.2	44	51	1106	1510	6	9	25	37	5	11
1107	2-3	37	57	1255	1670	6	7	38	73	12	24
1153	3-4	45	58	1156	1470	5	8	36	69	14	35
1209	4-2	50	55	890	1050	0	2	23	37	2	11
1225	2-1	52	59	810	970	0	2	20	31	-	-
1229	1	44	51	200	1040	2	10	11	69	3	57
1248	1-2	54	59	746	1020	5	7	19	36	9	17

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 11/17/78 SCOUT: OVER POINT 1
CARTRIDGE/PASS: 1617 1 MIN. GROUND ELEV.: 91 M(MSL)
TIME: 9:27:52 TO 9:44:40

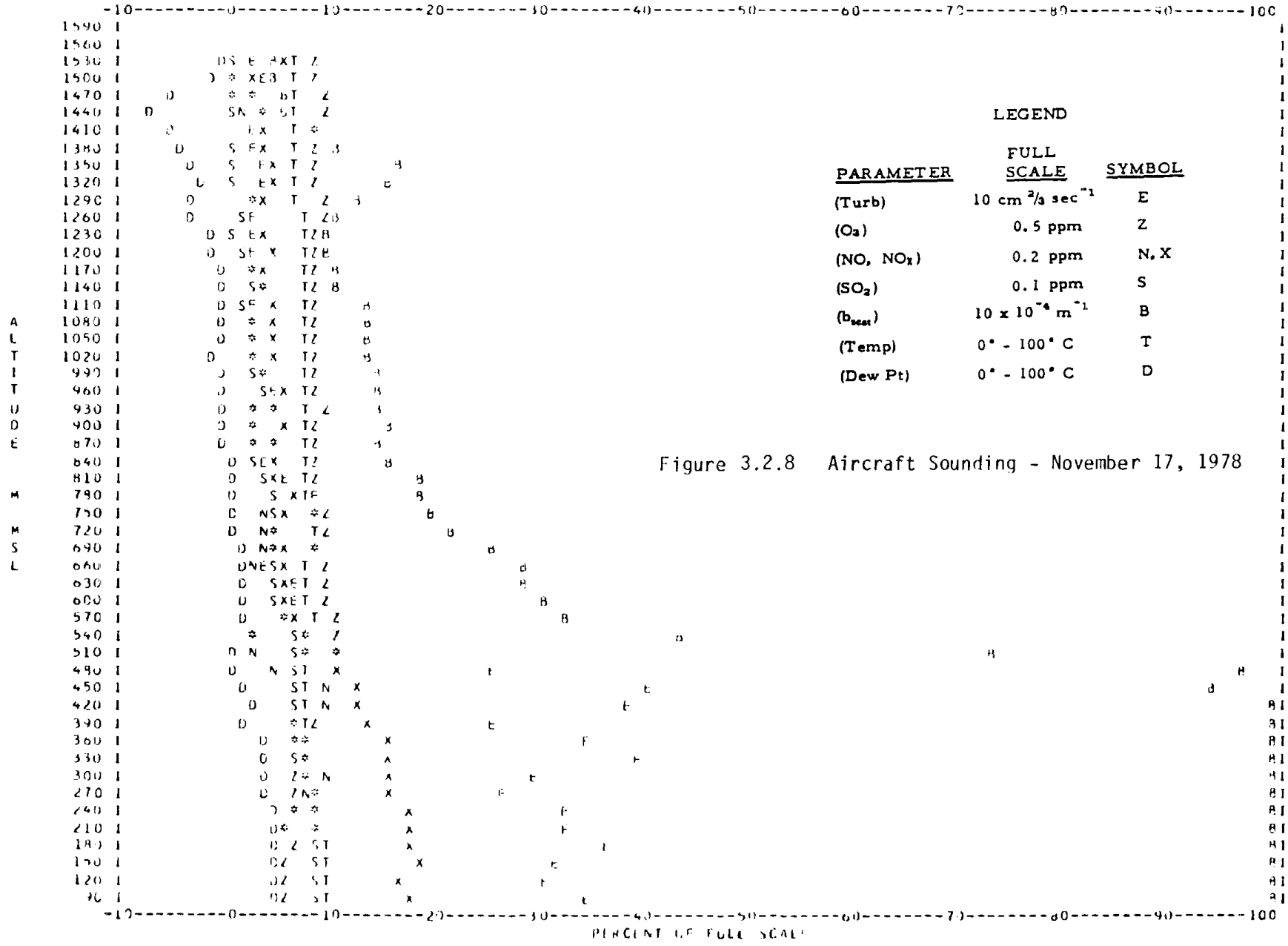


LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100°C	T
(Dew Pt)	0° - 100°C	D

Figure 3.2.7 Aircraft Sounding - November 17, 1978

DATE: 11/17/78 ROUTE: TOP POINT 4
CARTRIDGE/PASS: 1617 4
TIME: 10:34:40 TO 10:45:23 MIN. GROUND ELEV.: 91 M(MSL)



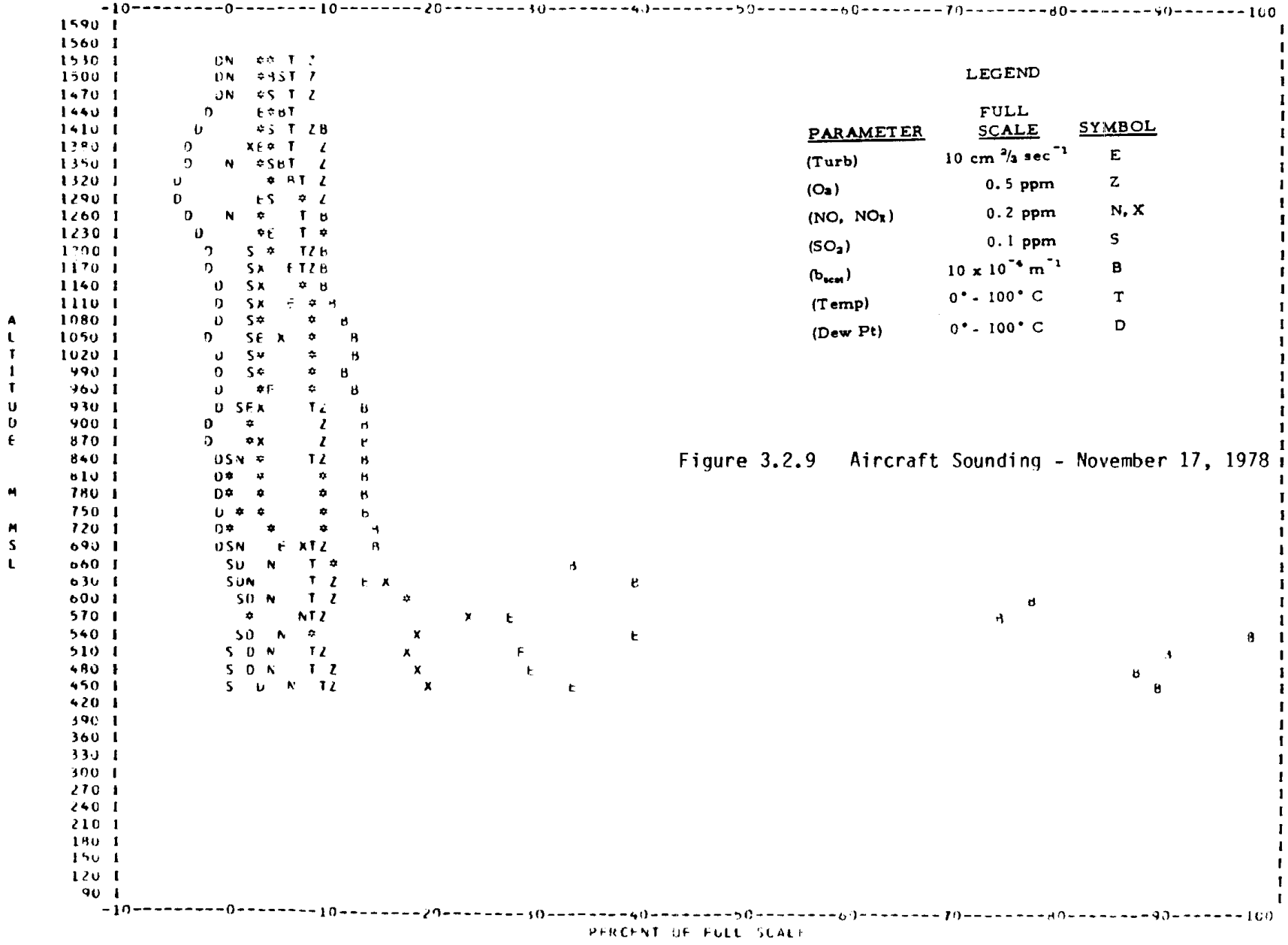
LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 $cm^{2/3} sec^{-1}$	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	$10 \times 10^{-4} m^{-1}$	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.2.8 Aircraft Sounding - November 17, 1978

DATE: 11/17/78
CARTRIDGE/PASS: 1617 10
TIME: 12:29:45 TO 12:36:32

ROUTE: DV R POINT 1
MIN. GROUND ELEV.: 91 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_2)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.2.9 Aircraft Sounding - November 17, 1978

- Background ozone and NO_x concentrations were 45 ppb and 20 ppb respectively.
- Large ozone deficits were observed within the urban plume (Figure 3.2.10).
- Insignificant amounts of SO_2 were observed both in and outside of the urban air.
- The southern leg of the sampling triangle defined a broad and somewhat diffused urban plume roughly 12 nm wide with NO_x concentrations approximately twice that of the background air.
- The first pass along the northern leg of the sampling encountered only local sources over the north Fresno area. However, 1-1/2 hours later on the second pass along that route, it appears that the urban plume had moved north and now extended along the entire traverse east of Highway 99.
- The urban plume remained east of Highway 99 throughout the sampling.
- Superimposed on the broad urban plume were more localized sources which were characterized by a complex ozone and NO_x structure.

Aircraft Sampling - 18 November 1978

In conjunction with the tracer release from downtown Fresno, aircraft sampling was conducted to determine the transport and diffusion of the urban plume. Traverses were flown approximately 5, 10, and 15 miles downwind, perpendicular to the plume axis, and at two altitudes within the mixing layer. An upwind traverse defined the background air quality and a downwind spiral defined the distribution of parameters in the vertical.

Figure 3.2.11 shows the flight pattern utilized on November 18. Table 3.2.7 gives the maximum concentrations of several parameters observed on the various segments of the pattern.

A detailed sounding at 1436 PST is shown in Figure 3.2.12. The surface mixed layer extended to about 540 m (agl). Ozone, NO_x and b_{scat} values were all elevated within the layer and were well-mixed.

DATE: 11/17/78
CARTRIDGE/PASS: 161/ 7
PASS START TIME : 11:53:21

ROUTE: POINT 3 TO POINT 4
ALTITUDE: 457 M(MSL)

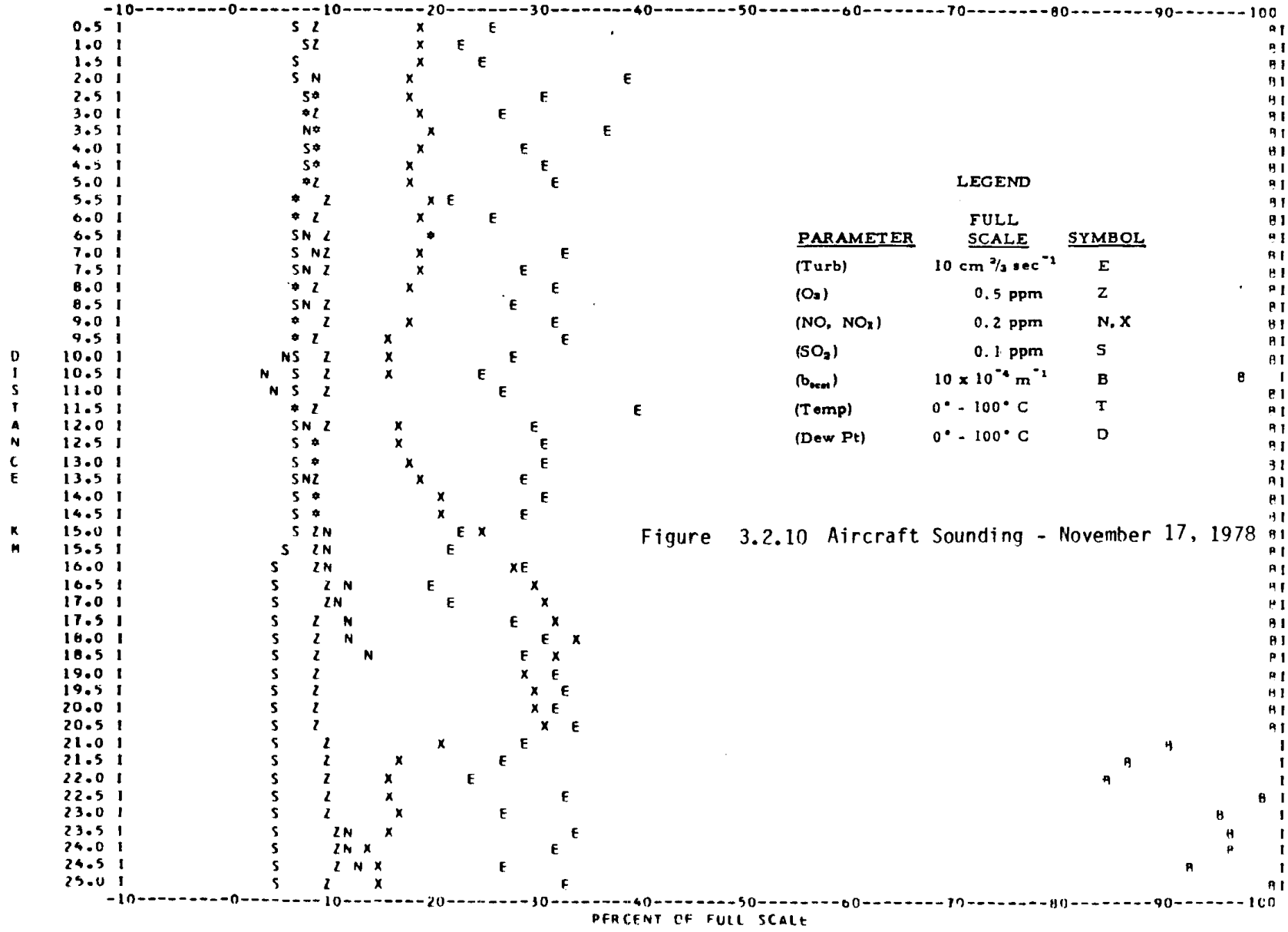
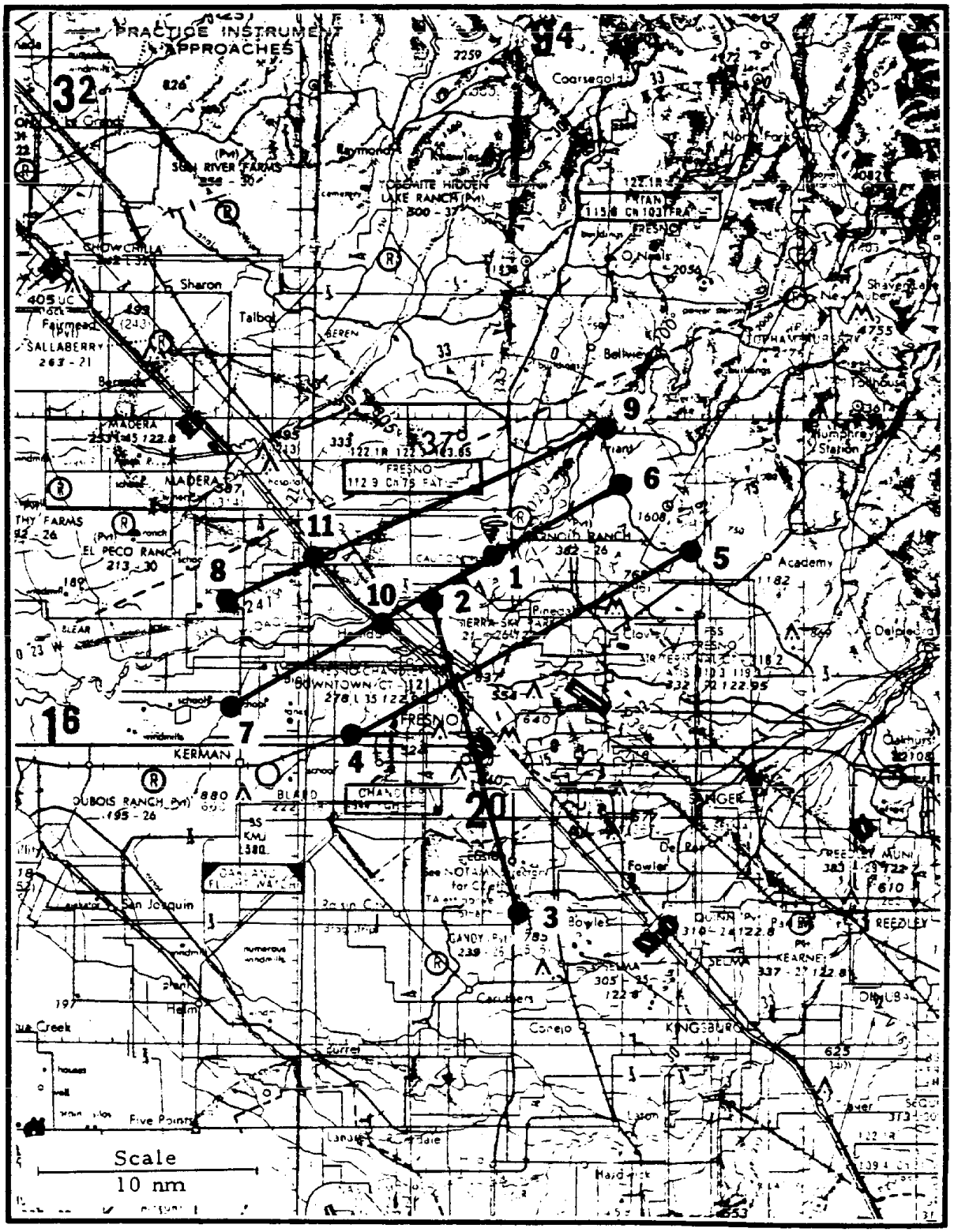


Figure 3.2.10 Aircraft Sounding - November 17, 1978



SAMPLING ROUTES 18 November 1978

Figure 3.2.11

Table 3.2.7

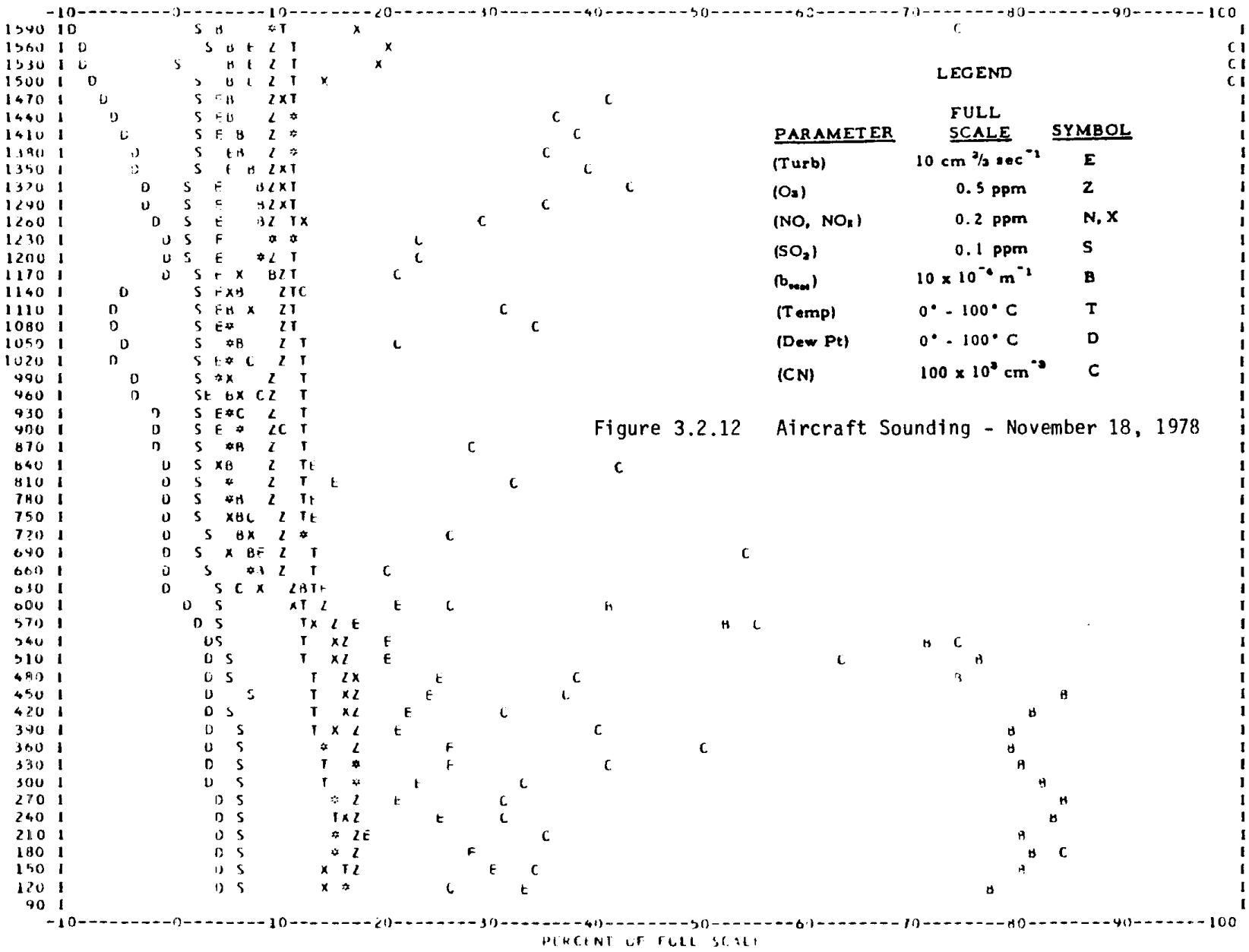
AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 18, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1424	1	58	88	267	920	3	11	22	44	-	-
1456	2-3	76	83	705	860	5	9	24	47	7	12
1524	4-5	75	84	741	890	4	5	28	57	9	19
1546	6-7	75	87	706	910	2	4	29	54	6	11
1616	8-9	77	87	734	930	5	14	29	50	6	13
1643	5-4	64	79	712	900	6	7	34	58	6	11
1701	10-6	70	81	745	910	6	7	30	48	7	12
1719	9-10	72	86	731	870	6	15	36	52	7	13

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 11/18/78
CARTRIDGE/PASS: 1627 1
TIME: 14:24:56 TO 14:36:48

ROUTE: OVER POINT 1
MIN. GROUND ELEV.: 91 M(MSL)



LEGEND

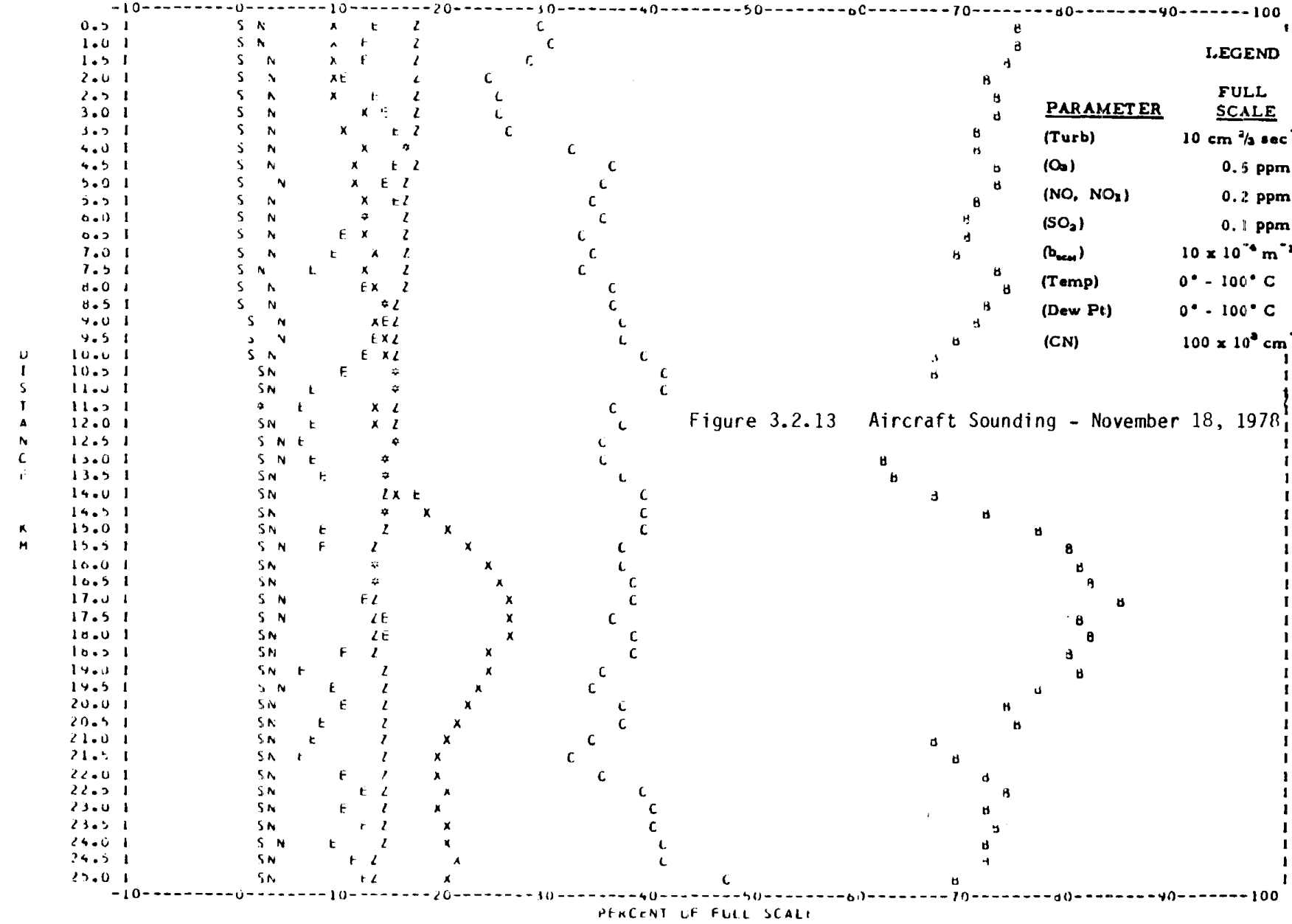
PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_2)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Figure 3.2.12 Aircraft Sounding - November 18, 1978

The urban plume was easily distiguishable at all downwind distances (e.g., Figure 3.2.13) by significant increases in CN, b_{scat}, and oxides of nitrogen. Background NO_x concentrations in excess of 50 ppb were observed within the urban air. Ozone depletion was observed within the urban plume at all downwind distances. The nearby constant levels of NO_x observed within the urban air and the constant plume width at all distances downwind suggest slow plume diffusion. The plume was located east of Highway 99 and extended into the Sierra foothills north of Fresno. The tracer plume coincided exactly with the urban plume as defined by the air quality further documenting the pollution source. SO_2 was not observed in any significant amounts. Visibilities were restricted to less than three miles throughout the sampling.

DATE: 11/18/78
CARTRIDGE/PASS: 1677 5
PASS START TIME : 15:46: 8

ROUTE: POINT 6 TO POINT 7 (CONTINUED)
ALTITUDE: 457 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBO
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_2)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Figure 3.2.13 Aircraft Sounding - November 18, 1978

3.2.3 Tracer Test 2

Release Location: Fresno, Fresno County
Time and Date: 1300-1700 PST, 11/18/78
Amount: 94 pounds of SF_6 per hour
Release conducted during light and variable winds

Initial northward transport

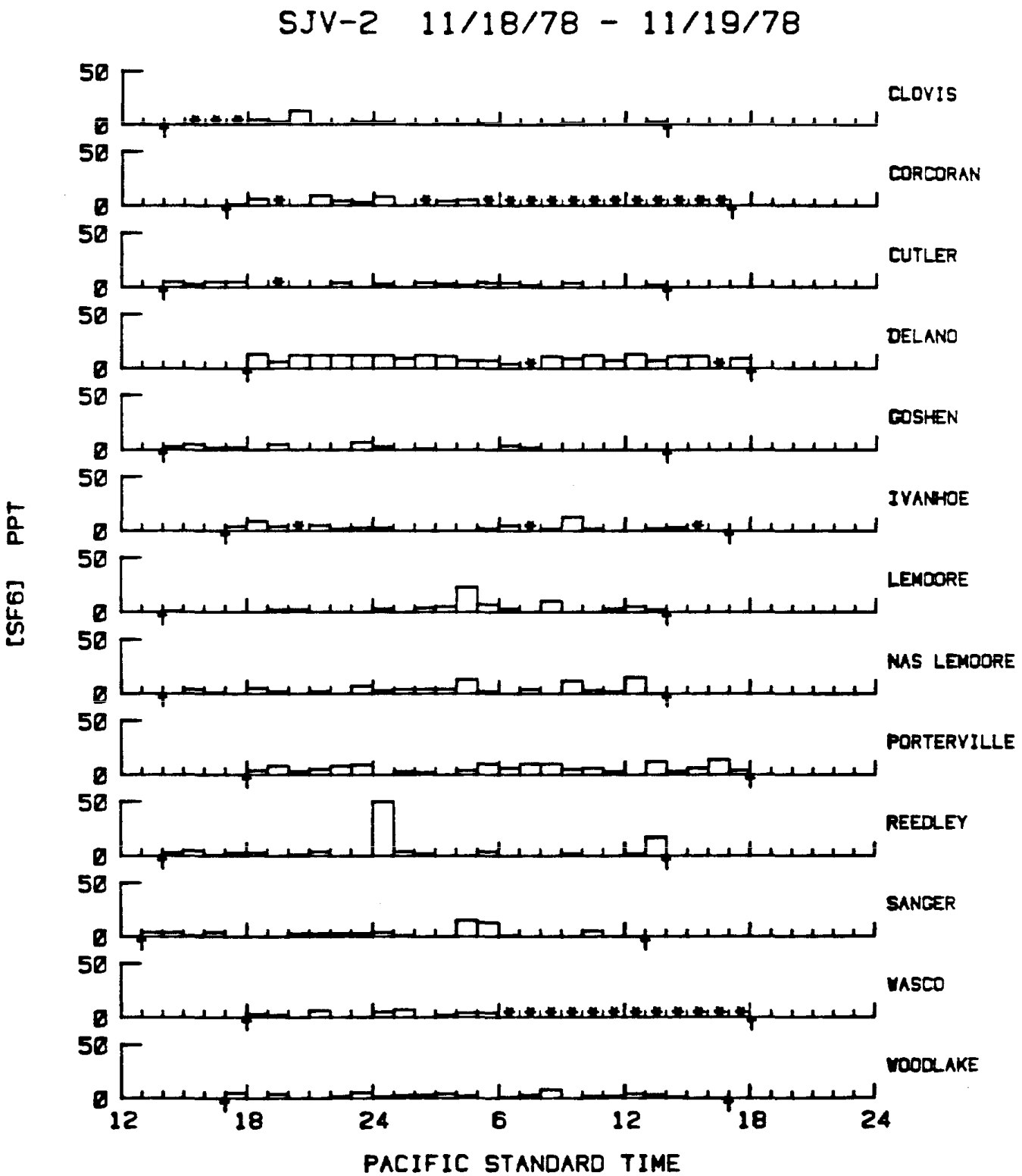
SF_6 was first detected near Fresno about 1600 PST during Automobile Traverse 2-1. The highest SF_6 concentrations were detected near Clovis, about 6 miles north of the release site. Because of the uncertainty in wind direction, it is difficult to accurately estimate the crosswind standard deviation in concentration of the SF_6 plume. The value of this parameter, used in the Gaussian plume model, was about 1/2 to 3/4 miles at this distance downwind. Within the context of the Gaussian plume model, the horizontal dispersion corresponded to unstable atmospheric conditions (approximately between Pasquill-Gifford stability classes B and C). The initial dispersion of the tracer was presumably enhanced by building induced turbulence and the urban heat island effect rather than the regional atmospheric stability. An SF_6 plume was detected at about the same location during Traverses 1-2 and 2-2. The SF_6 levels detected during Traverse 1-2 were about an order of magnitude lower than those detected during either of the other traverses. This illustrates the uncertainties associated with sampling intervals of the same order as the width of the plume in that a sample may not have been collected near the location of the maximum concentration. Northward transport of the tracer was also indicated by airplane traverses. SF_6 was detected as far as 15 miles north of the release site. Where both airplane and automobile traverses were conducted near the same locations, good agreement was found between the concentrations detected by the different sampling methods.

Transport by drainage winds near end of release

As described above, some of the tracer was transported towards the north. Large SF_6 concentrations were detected near the center of the Fresno metropolitan area, however, during Traverses 1-5, 2-4, and 3-3. These traverses, conducted between 2000 and 2300 PST, detected SF_6 near the intersection of Highways 99 and 180. This material apparently represented SF_6 released about the time the nighttime drainage winds (easterly flow) began to develop. The tracer concentrations detected in the vicinity of Freno were higher than those detected previously, suggesting that significant pooling of the tracer occurred due to the light wind conditions.

Transport southward during night and following morning

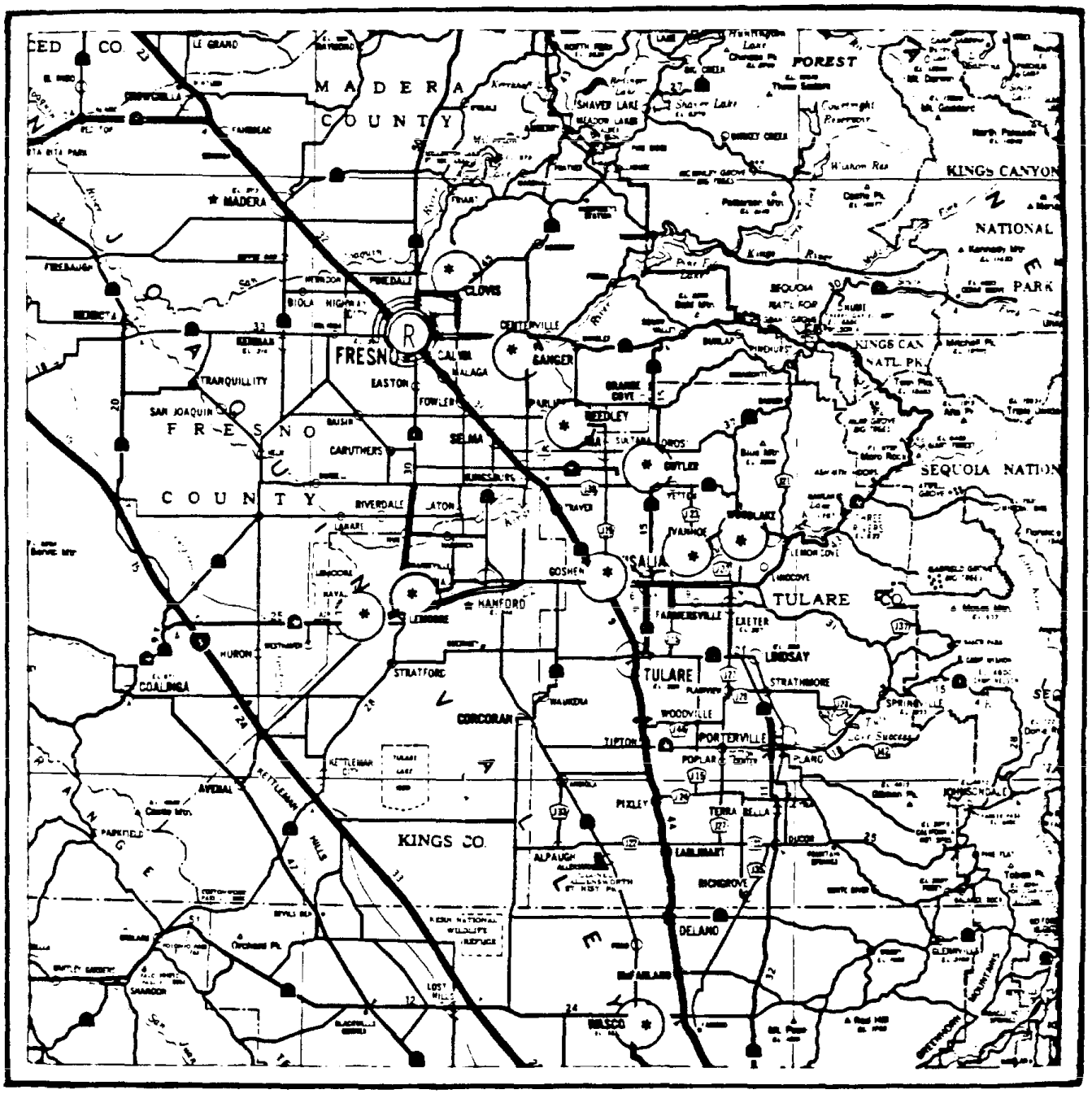
During the night following the release, northerly winds developed at Fresno, as exemplified by the surface winds at 0700 PST on 11/19/78. This caused the SF_6 to be transported towards the south. The fixed site sample data are shown in Figure 3.2.14 and the sampler locations are shown in Figure 3.2.15. A maximum hourly-averaged SF_6 concentration of 23 ppt was detected at Lemoore, about 30 miles south of Fresno, between 0400 and 0500 PST on 11/19/78. At the same time 13 ppt was detected at the neighboring Lemoore Naval Air Station. At about 0800 PST, a maximum concentration of 89 ppt was detected just south of Fresno along Highway 41 during Traverse 3-4. The SF_6 detected at Lemoore at 0400 PST probably corresponded to the tracer detected in the center of Fresno on the previous evening, while the SF_6 detected just south of Fresno during Traverse 3-4 probably corresponded to the tracer initially transported north. SF_6 was also detected at the southern San Joaquin Valley site of Delano. SF_6 concentrations of about 10 ppt were detected from 1800 PST, 11/18/78 until the conclusion of the sampling period at 1800 PST, 11/19/78. The tracer detected on the evening of 11/18/78 was probably due to the carryover from the previous test. No other samples were available, however, to verify this conclusion.



RELEASE: 470 LBS SF6 AT FRESNO
RELEASE TIME: 1200-1700 PST, 11/18/78

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.2.14



(*) INDICATES SAMPLER LOCATIONS

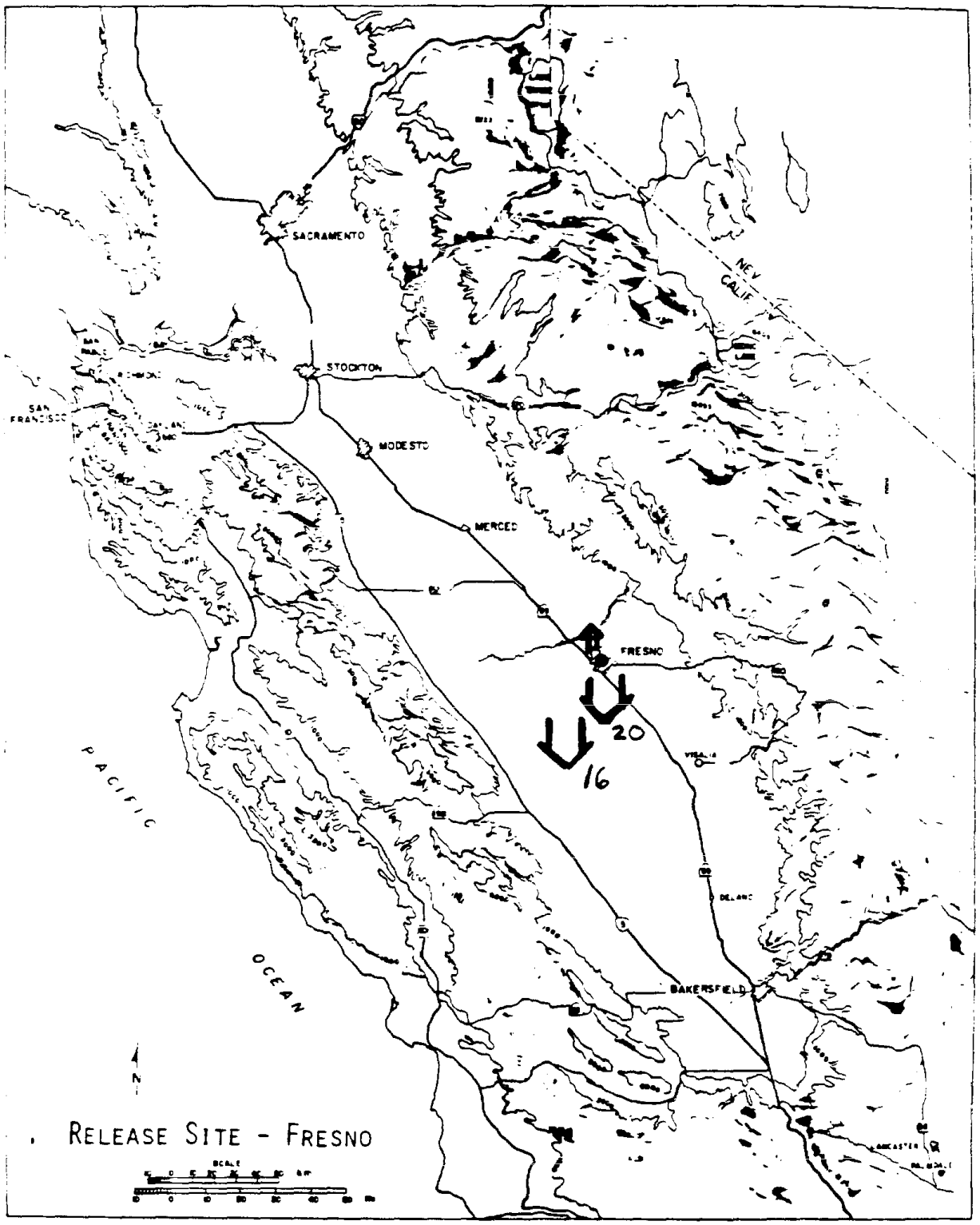
(R) IS THE RELEASE SITE

Figure 3.2.15

Summary

During this experiment, the transport and dispersion of the Fresno urban plume was investigated by a tracer release in central Fresno. As during the first tracer experiment wind speeds throughout the San Joaquin Valley were generally light. At the release site, generally southerly winds persisted throughout the afternoon of the release. The majority of the SF_6 was thus transported towards the north. The initial tracer dispersion roughly corresponded to moderately unstable atmospheric conditions within the context of the Gaussian plume model. By about 1900 PST, an easterly drainage wind had developed at Fresno. SF_6 released during the wind transition stagnated around Fresno and apparently separated from the earlier northward moving plume. By nightfall all of the released tracer remained within about 20 miles of the release site. During the early morning hours of the following day, the tracer was transported back towards the south. SF_6 probably corresponding to that which had previously stagnated over Fresno, was detected near Lemoore between 0400 and 0500 PST. The SF_6 initially transported towards the north was probably conveyed by the nighttime drainage flow towards the center of the valley and again southward by the morning northerly flow. Part of this SF_6 was detected directly south of Fresno at about 0800 PST, 11/19/78. Figure 3.2.16 displays an overview of the tracer transport during this test.

Analysis of the tracer data suggests that little or no SF_6 was transported out of the boundaries of the valley by the day following the release. It was not possible to accurately estimate the mass of SF_6 remaining within the valley, but the transport path of the tracer was not toward the valley boundaries. Significant loss of the tracer may have occurred through vertical mixing but it was impossible to quantify the importance of this mechanism on valley ventilation. Low but non-zero SF_6 concentrations were detected throughout the test in Delano, at the southern end of the valley. This SF_6 was presumably carryover from the test conducted three days prior to the current experiment. It is apparent that carryover of pollutants into subsequent days can be significant. During the first experiment, most of the released tracer was detected during the following day. During this test, it was impossible to estimate the mass of SF_6 left within the valley but the characteristics of the tracer transport and dispersion were very similar to the first test.



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (1200 PST, 11/18/78)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.2.16

3.3 Test 3 25-26 November 1978 - Bakersfield Release (1200-1700 PST)

3.3.1 Meteorology

General

On the morning of the 25th, an upper level closed low pressure area which had passed over Central California on the previous day was centered near the Nevada-Utah border. Although the precipitation resulting from this system had ceased, the associated cold unstable air was still affecting Central California. As a consequence, relatively good visibilities and deep mixing potential prevailed. This surface weather map is shown in Figure 3.3.1.

As can be seen in Section 2, a period of stabilization was beginning although the 850 mb temperature was 4°C, more than 7° below the 5-year average. Visibilities on the 25th ranged from 7 to 15 miles in the the Bakersfield area. Only high scattered clouds were observed in the valley but a few scattered cumulus formed over the mountains during the afternoon. Bakersfield reported a maximum temperature of 66°F or near normal for November. Dense fog formed on the morning of the 26th, restricting visibility to as low as 1/8 mile. Visibility increased to 10 miles late in the day. Maximum surface temperature reported at Bakersfield was 62°F.

The streamlines depicted on Figures 3.3.2 through 3.3.4 describe the regional surface flows during the test. The flow early in the release period can be represented by the 1300 PST streamlines (Figure 3.3.2). Flows were generally light and from the northwest in the middle of the valley, diverging into the foothill regions. In the Bakersfield area, wind speeds were on the order of 2-3 m/sec. The northerly flow patterns are characteristic of relatively deep mixing and transport over the Tehachapi Mountains southeast of Bakersfield.

By 1900 PST stability-dominated flow developed and a short-lived eddy was formed at the southern end of the valley (Figure 3.3.3). Drainage flows began to set up in the other portions of the valley and converging air from the surrounding mountains indicates movement into the valley from all directions and along the valley axis to the northwest. A convergence zone in the center of the valley is indicated in Figures 3.3.3 and 3.3.4. The drainage flows, once established, persisted until after 1000 PST on the following morning.

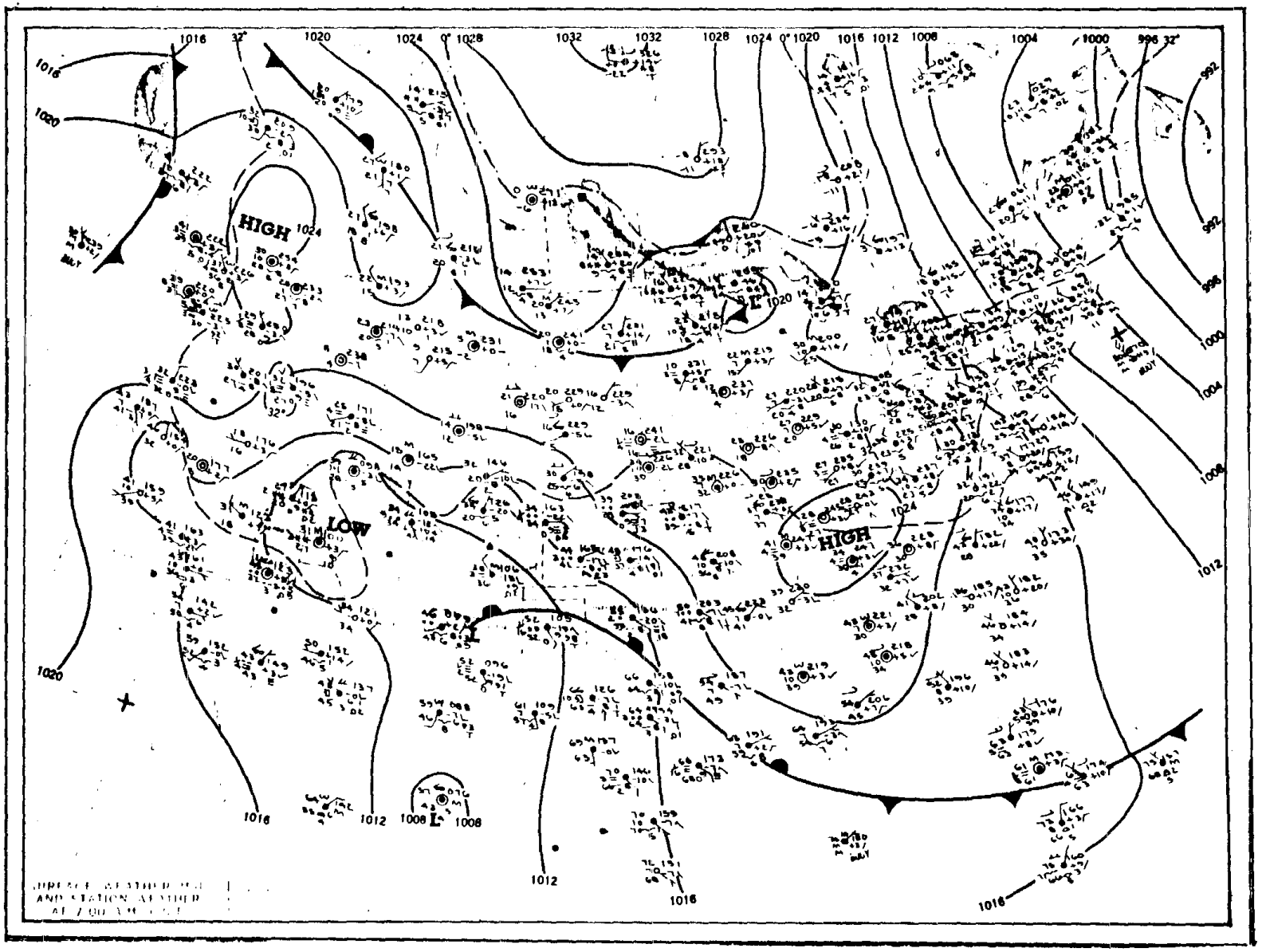


Figure 3.3.1 Surface Weather Map - November 25, 1978

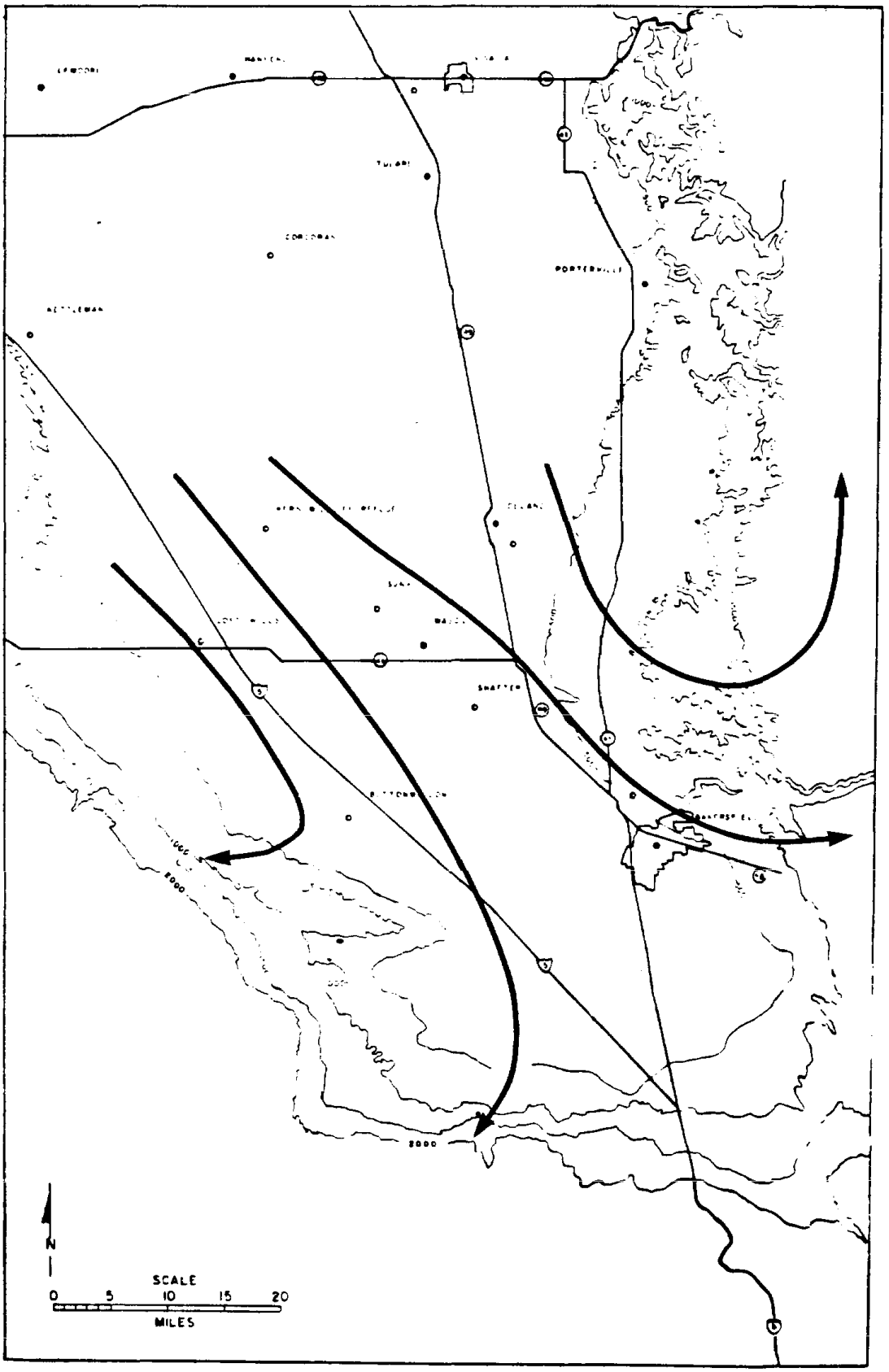


Figure 3.3.2 Surface Streamlines - 25 November 1978 (13 PST)

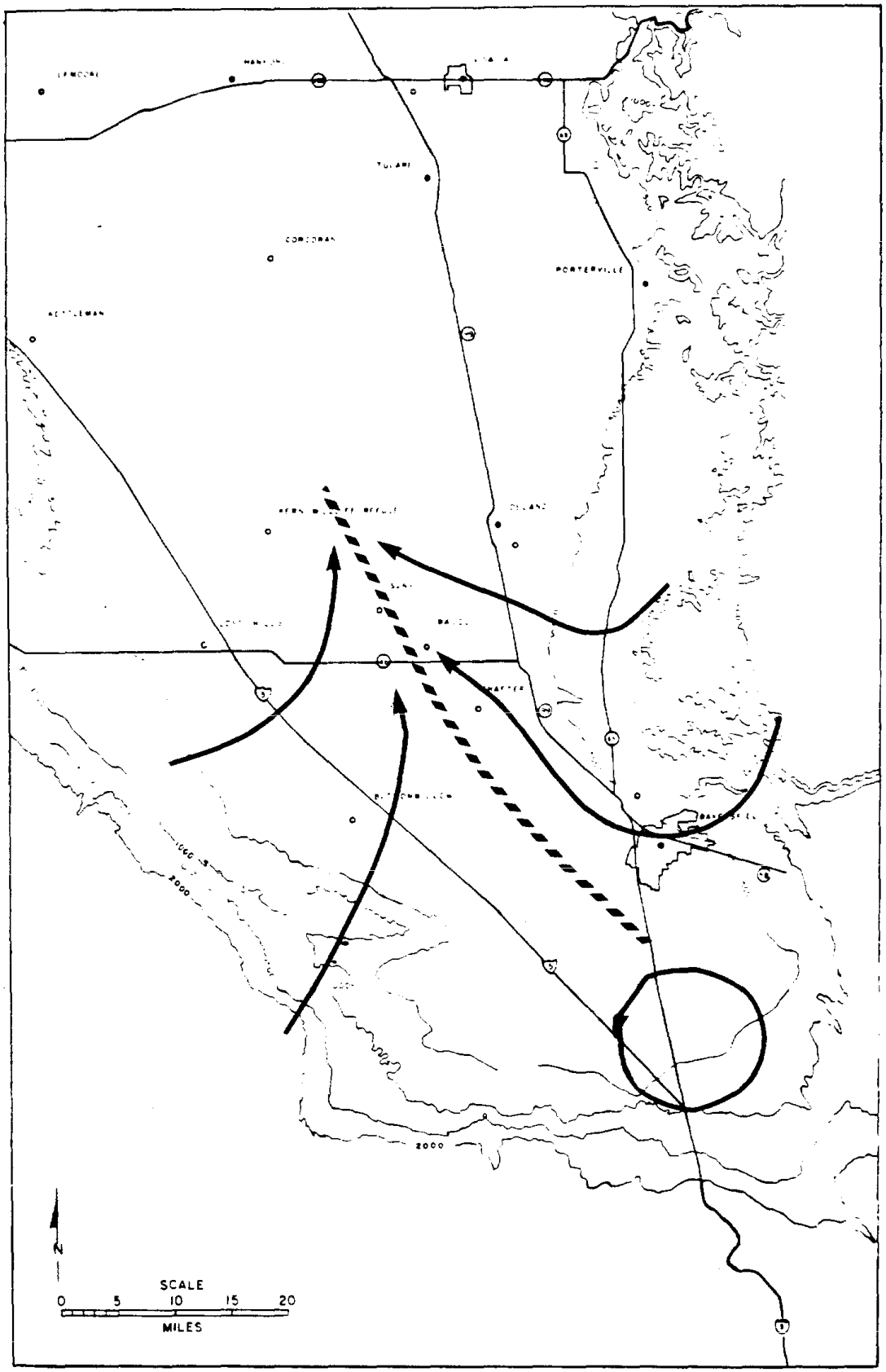


Figure 3.3.3 Surface Streamlines - 25 November 1978 (19 PST)

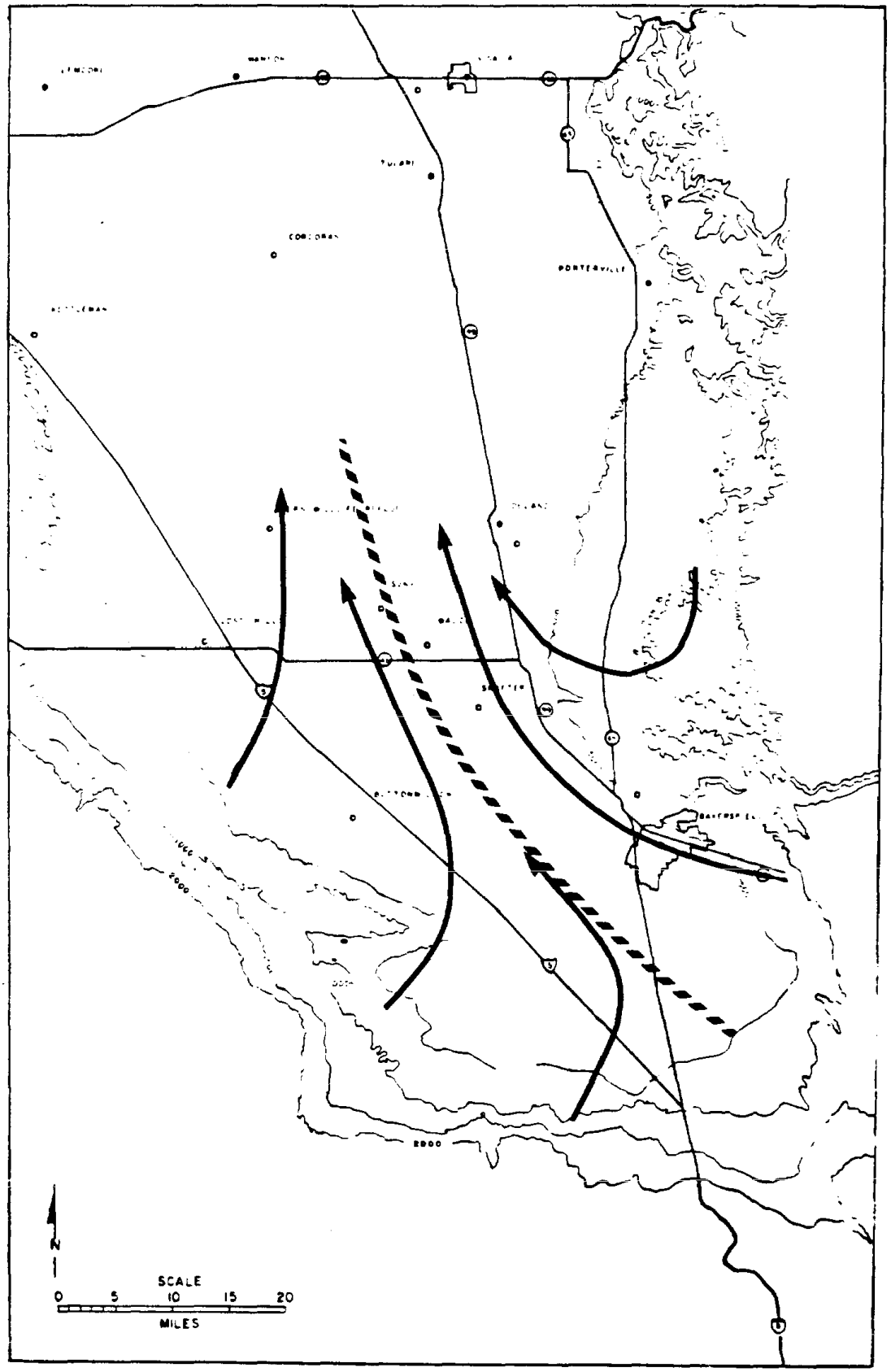


Figure 3.3.4 Surface Streamlines - 26 November 1978 (07 PST)

Transport Winds

Surface winds at Bakersfield Airport on November 25-26 (Table 3.3.1) show the diurnal changes in wind regime typical of the southern part of the valley. Northwest winds prevail through 1600 PST followed abruptly by easterly and then southerly drainage winds which lasted throughout the night.

Table 3.3.1

SURFACE WINDS - BAKERSFIELD AIRPORT
NOVEMBER 25-26, 1978

Time (PST)	Wind	Time (PST)	Wind
1200	290°/2.1 m/s	2200	320°/2.1 m/s
1300	260 /2.1	2300	Calm
1400	260 /4.1	0000	090 /2.1
1500	330 /3.1	0100	120 /2.6
1600	330 /3.1	0200	190 /1.0
1700	020 /3.1	0300	200 /1.0
1800	030 /3.1	0400	130 /2.1
1900	060 /3.1	0500	140 /3.1
2000	080 /1.5	0600	130 /2.6
2100	050 /2.1	0700	Calm

Table 3.3.2 gives the 1000-foot winds at Bakersfield and Bealville for November 25-26. Bealville is located about 25 miles southeast of Bakersfield in the valley along Highway 58. The winds at Bakersfield show northwesterly to northerly directions through 03 PST, followed by east to southeast winds through 12 PST. At Bealville the 1000-foot wind directions were west to northwest except for a brief period of easterly flow around 07 PST on November 26.

Table 3.3.2

1000-FOOT WINDS

Date	Time (PST)	Bakersfield Wind	Bealville Wind
11-25	11	326°/2.4 m/s	
	12	293 /2.1	283°/5.8 m/s
	13	267 /2.7	273 /7.9
	14	276 /2.3	285 /4.3
	15	320 /3.3	267 /4.2
	16	342 /3.8	271 /3.4
	17	352 /4.6	276 /4.9
	18	354 /2.4	286 /4.5
	19	334 /3.1	284 /2.5
	20		280 /3.5
	21	23 /2.9	275 /2.9
11-26	00		272 /1.1
	01	28 /1.5	
	03		306 /2.1
	04	64 /2.2	
	07	117 /3.2	80 /1.7
	09		262 /3.3
	11	83 /1.4	278 /2.9
	12	60 /0.7	267 /3.0
	13	320 /2.8	265 /3.8
	14	303 /1.4	296 /1.8

These observations indicate that the drainage flow at Bakersfield reached a depth of over 1000 ft by early morning and was followed by a return to northwesterly winds after 12 PST. At Bealville air at 1000 ft could escape through the pass toward Tehachapi except for a brief period near early morning. Tracer material mixed to over 1000 ft during the afternoon and therefore had an opportunity to escape from the valley during the afternoon and night. After stabilization occurred (17 PST) tracer material trapped in the surface layers could not have escaped from the valley until the northwest winds began the next day. During the night, therefore, the surface flows were dominated by drainage winds which carried material toward the northwest.

Mixing Heights

Mixing heights were measured by the aircraft on November 25-26 as follows:

Table 3.3.3

AIRCRAFT MIXING HEIGHTS

Time (PST)	Location*	Mixing Height (agl) (m)
	November 25, 1978	
1350	4 NNW BFL airport	1290
1737	4 NNW BFL airport	600
		(second layer top at 1000 m)
	November 26, 1978	
1118	4 NNW BFL airport	720
1203	22 N BFL airport	590
1515	14 NNW BFL airport	1350

* Distances in miles

3.3.2 Air Quality

Surface Air Quality

Maximum ozone concentrations on November 25 were low throughout the valley. Isolated maximum values of 0.05 ppm were observed in Fresno and at several locations in the southern part of the valley. Figure 3.3.5 shows the maximum ozone concentrations recorded at all stations for the day.

Table 3.3.4 gives the maximum concentrations of other parameters observed in the valley on November 25.

Table 3.3.4

MAXIMUM POLLUTANT CONCENTRATIONS
NOVEMBER 25, 1978

Location	CO (ppm)	SO_2 (ppm)	NO_x (ppm)
Fresno-Olive	12		
Oildale		0.07	
Fresno-Olive			0.50
Reedley			0.57
Radome		0.04	0.38
Lost Hills		0.10	0.55

Visibilities at 13 PST are given in Table 3.3.5 for a number of airports in the valley.

Table 3.3.5

1300 PST VISIBILITIES
NOVEMBER 25, 1978

Station	Visibility (miles)
Sacramento	4 H
Stockton	1 F
Modesto	10
Merced	3 H
Fresno	8
Lemoore NAS	3 H
Visalia	6 H
Bakersfield	10

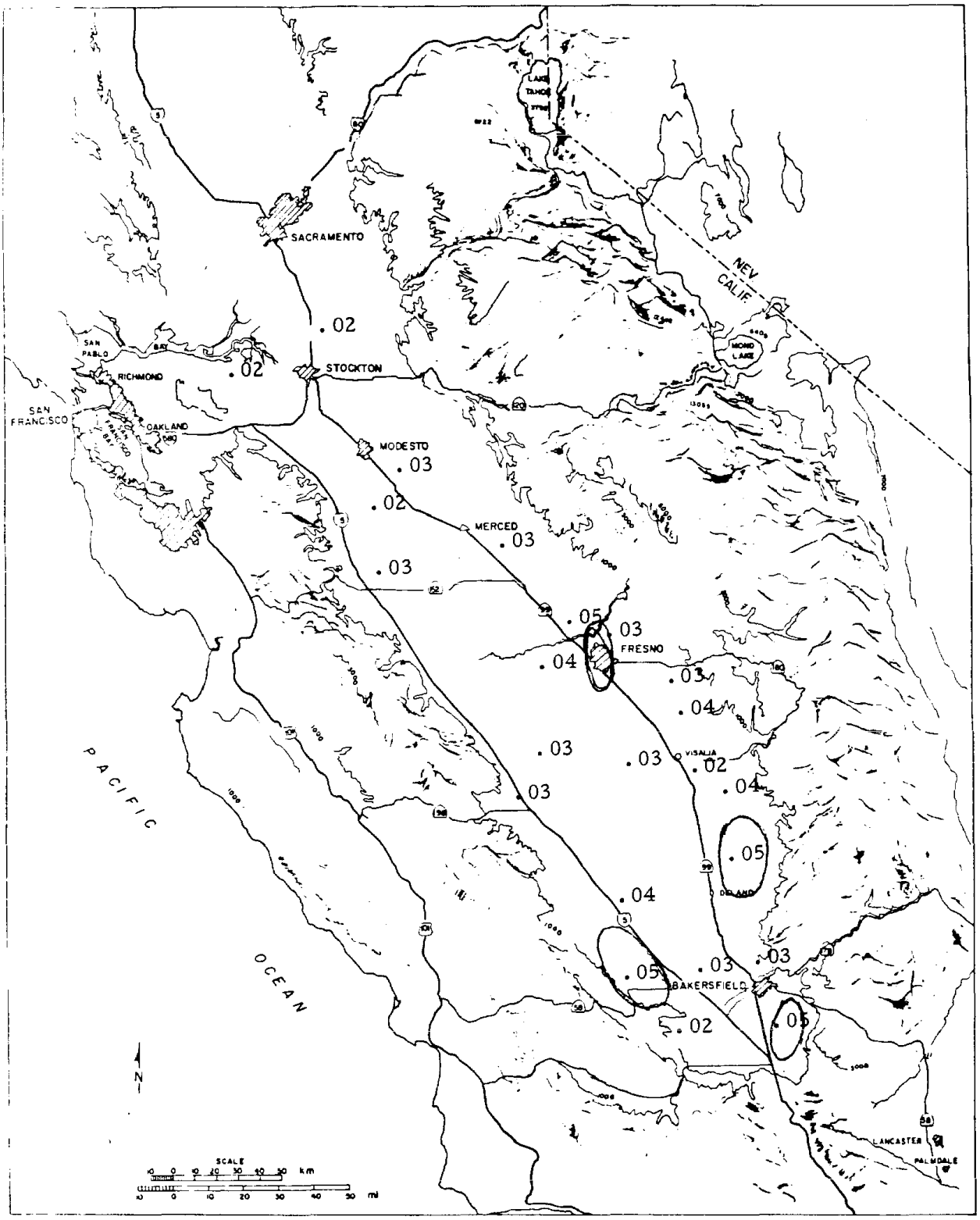


Figure 3.3.5 Maximum Hourly Ozone Concentrations (ppm) - November 25, 1978

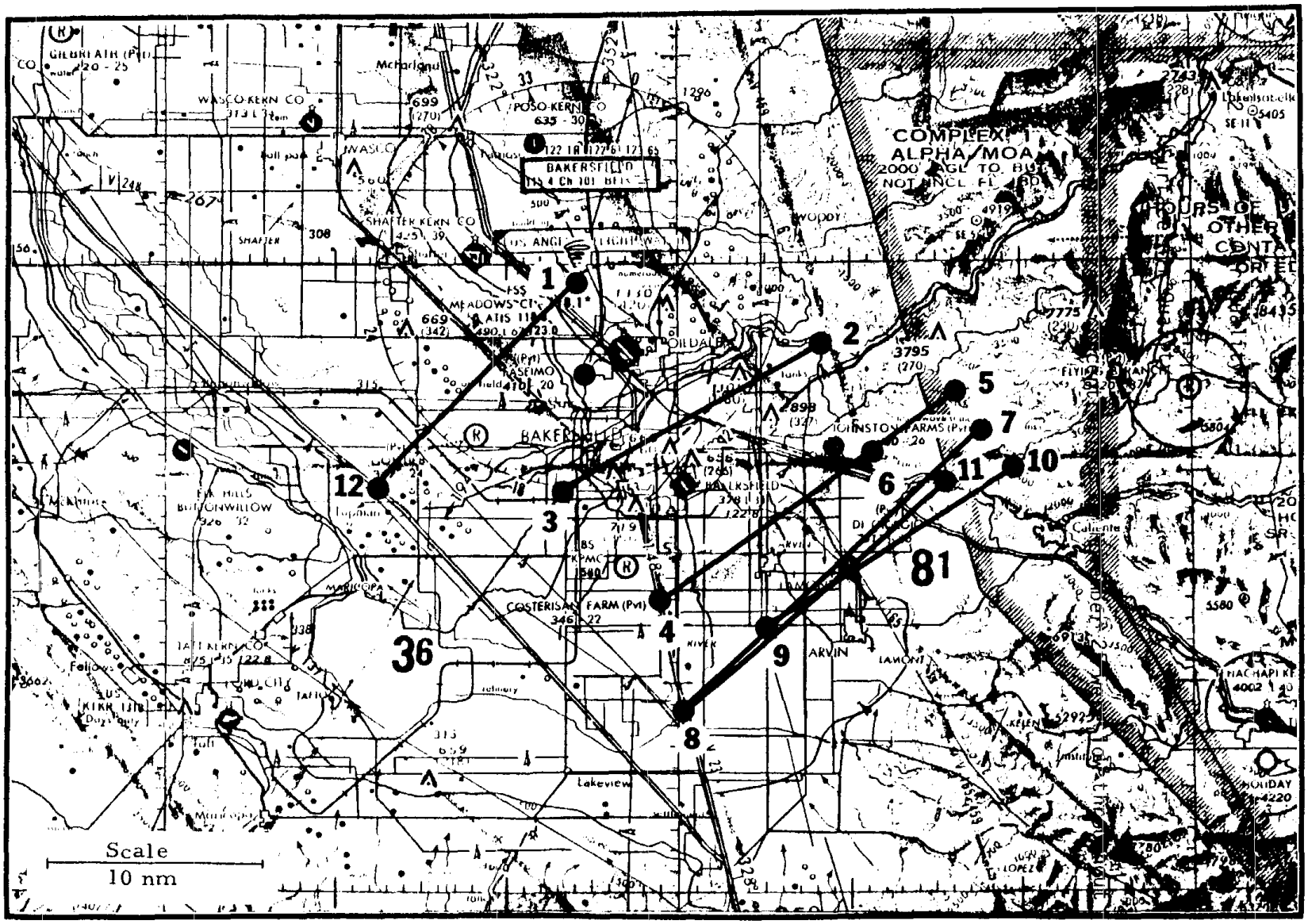
Visibilities at 1300 PST were variable throughout the valley, ranging from 1 to 10 miles. Restrictions were reported primarily as haze but light fog was observed at Stockton. The variations in visibility within the valley are attributable to the lack of pronounced stabilization following the passage of the closed low system through Central California.

Aircraft Sampling - 25 November 1978

In conjunction with the tracer release from Bakersfield, aircraft sampling was conducted to define the urban plume. Traverses were flown at approximate downwind distances of 4, 10, and 15 miles from Meadows Field at three altitudes within the mixing layer. An upwind traverse defined the background air quality and spirals over Meadows Field defined the depth of mixing during sampling. The four mile downwind traverse transected the city of Bakersfield in a northeast to southwest direction.

A map of the flight patterns on November 25 is shown in Figure 3.3.6. A summary of the pollutant concentrations found on each segment of the pattern is given in Table 3.3.6. Detailed soundings are included as Figures 3.3.7 and 3.3.8.

Strong vertical mixing from the surface to 1300 m ft-msl was evident at the start of sampling as shown in Figure 3.3.7. By the end of sampling, near sunset, the atmosphere had stabilized substantially (Figure 3.3.8) and the beginning of pooling of new pollutants is evident as indicated by the lower mixed layer depth and the increase in b_{scat} at low levels. Background concentrations of 10-20 ppb NO_x and 40-50 ppb ozone were observed. There was no evidence of an NO_x urban plume over the city or downwind. However, downwind from the Oildale area and the Kern River oilfields a well-defined NO_x/SO_2 plume was observed. The plume width was about four miles wide on the first downwind leg and six miles wide on the 10 mile downwind traverse (Figure 3.3.9) and was found at all altitudes flown. Although the NO_x and SO_2 concentrations measured were low, the plume was still easily discernible from the background air. The extension of the plume at the 15 mile downwind leg is not obvious, but NO_x/SO_2 plumes from more localized sources were observed.



SAMPLING ROUTES 25 November 1978

Figure 3.3.6

Table 3.3.6

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 25, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1350	1	45	49	166	270	0	13	15	22	5	10
1418	2-3	41	50	164	230	10	36	19	31	7	13
1435	3-2	41	53	181	250	6	25	20	38	9	20
1452	2-3	42	52	142	260	11	29	18	38	8	18
1509	4-5	43	53	146	260	5	21	14	28	5	16
1528	5-4	39	58	171	250	4	13	17	26	5	10
1530	4-6	39	48	177	260	5	19	19	29	5	9
1611	7-9	47	53	129	230	1	10	10	20	3	7
1633	9-10	36	47	179	260	2	8	17	25	4	13
1658	11-9	39	47	177	250	8	34	14	25	4	11
1722	12-1	42	49	274	370	1	6	14	18	5	10
1737	1	46	53	152	340	1	10	9	17	5	9

*SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 11/25/78
CARTRIDGE/PASS: 1637 1
TIME: 13:50:58 TO 14: 0:42

RFCTR: OVER POINT 1
MIN. GROUND ELEV.: 152 M(MSL)

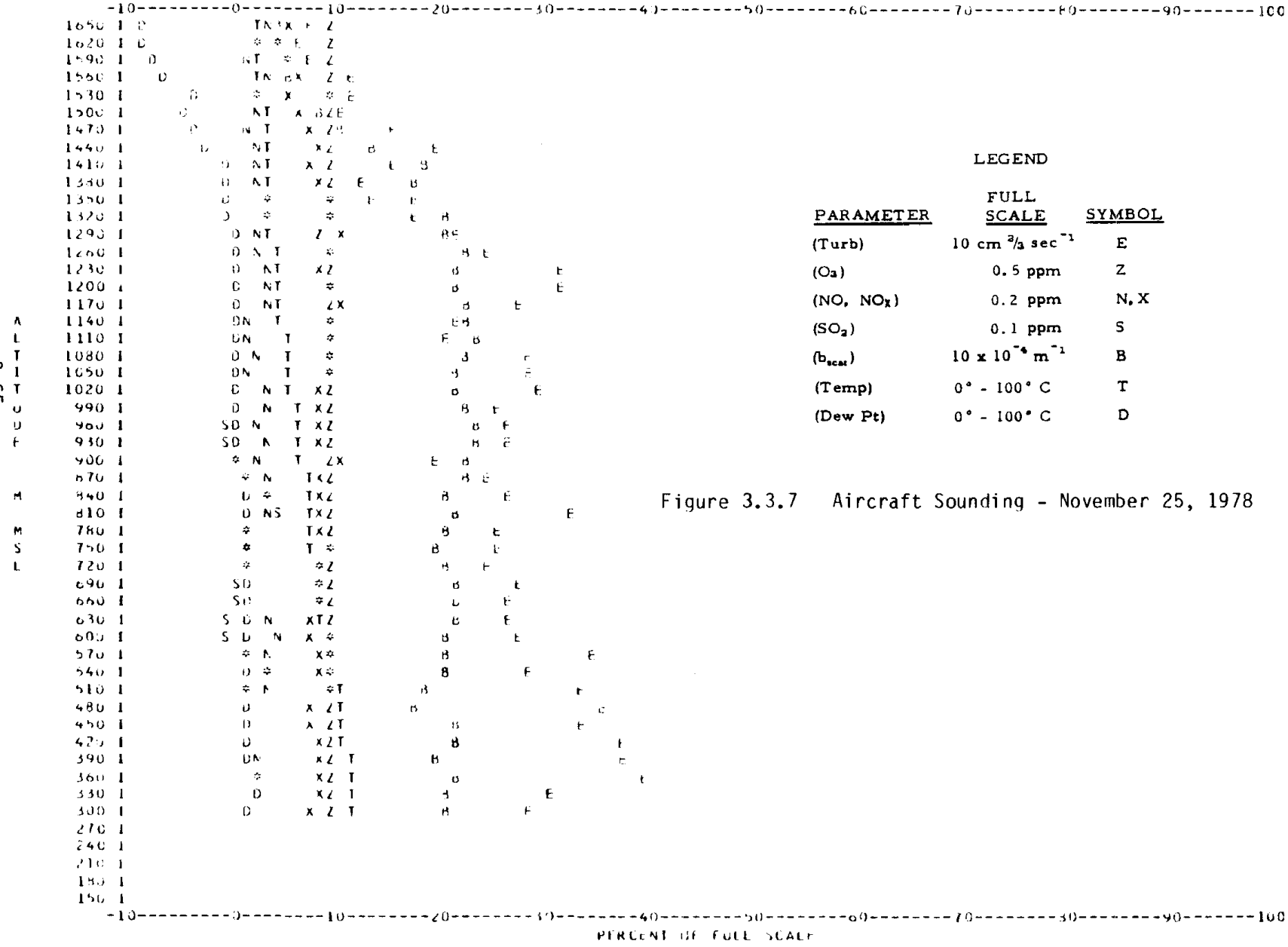


Figure 3.3.7 Aircraft Sounding - November 25, 1978

DATE: 11/25/78 ROUTE: OVER POINT 1
CARTRIDGE/PASS: 1647 13
TIME: 17:37:16 TO 17:43:42 MIN. GROUND ELEV.: 152 M(MSL)

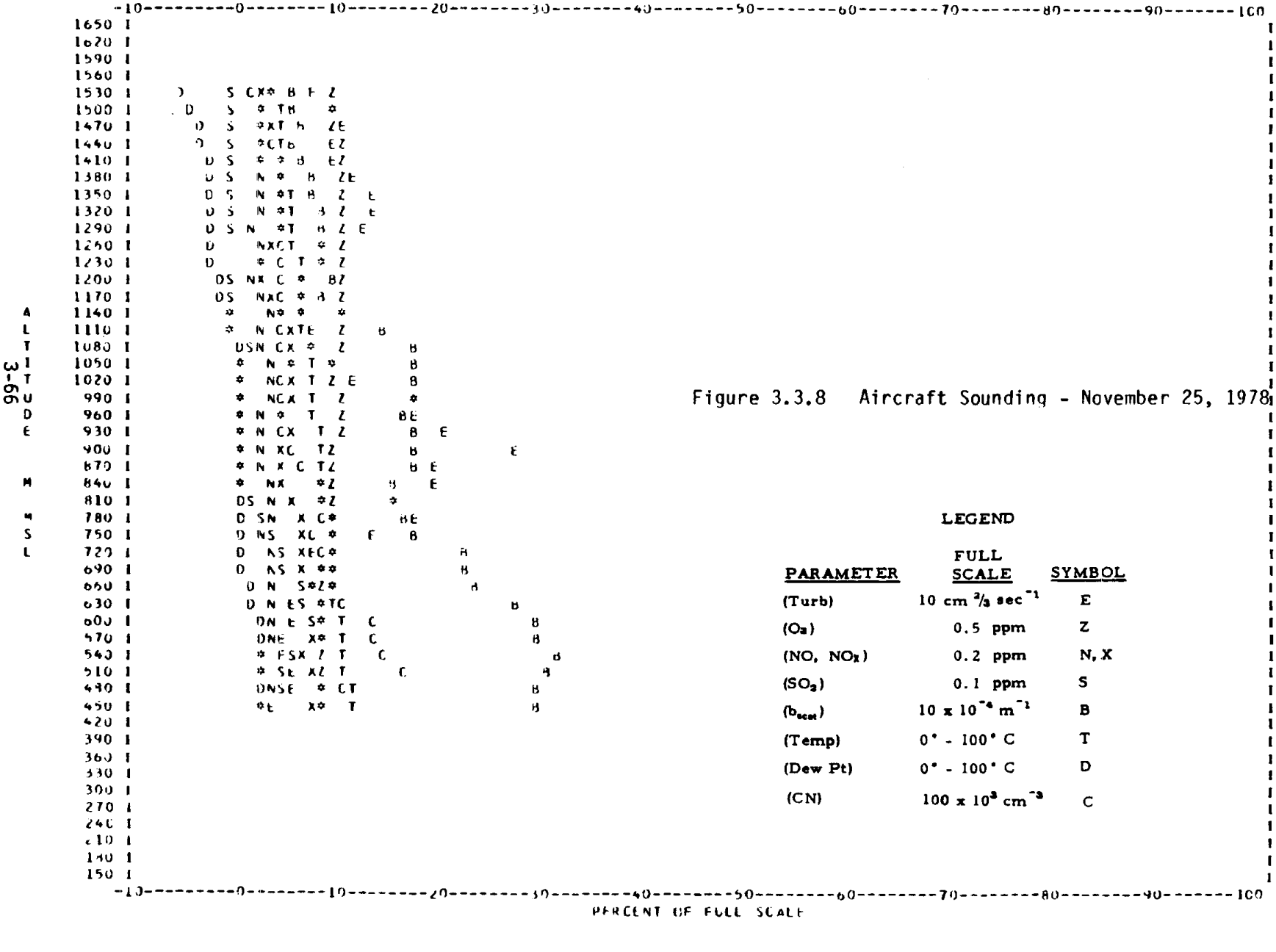


Figure 3.3.8 Aircraft Sounding - November 25, 1978

LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_2)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

DATE: 11/25/78 ROUTE: POINT 4 TO POINT 5
CARTRIDGE/PASS: 1637 8
PASS START TIME : 15:50:42 ALTITUDE: 457 M(MSL)

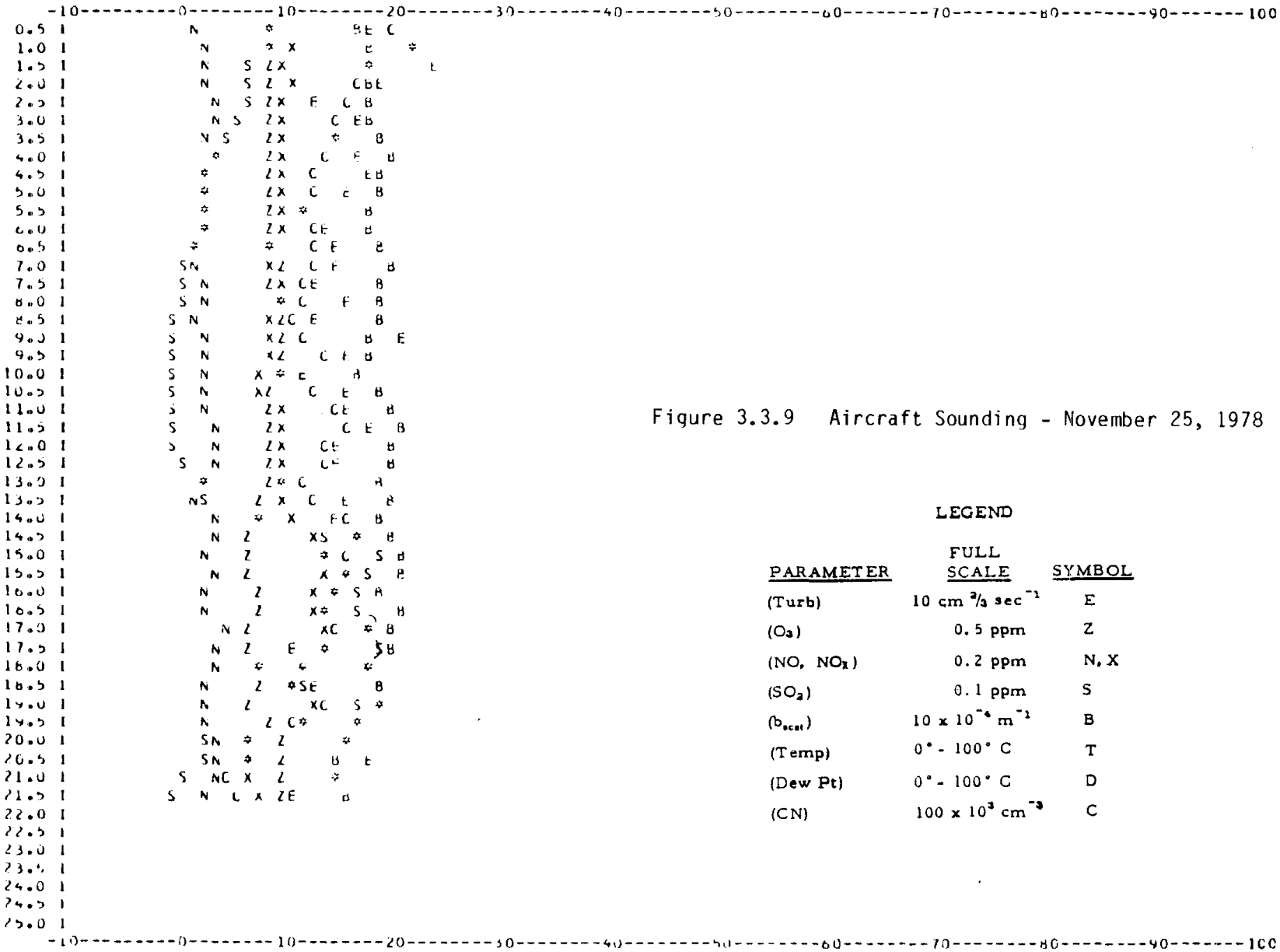


Figure 3.3.9 Aircraft Sounding - November 25, 1978

LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Aircraft - 26 November 1978

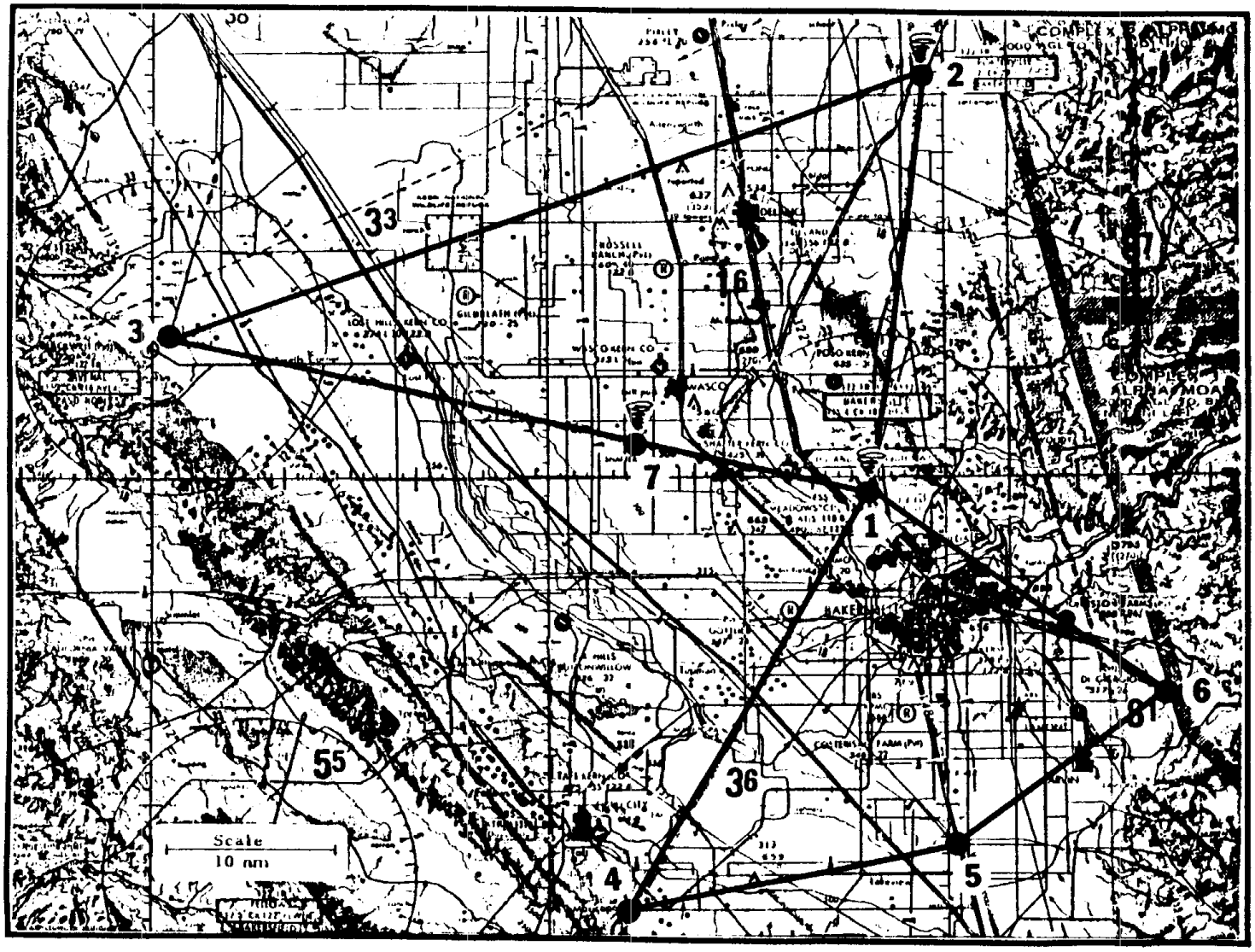
The purpose of this flight was to sample the regional air quality in the southern San Joaquin Valley. The flight plan was designed to provide wide aerial coverage from north of Lost Hills to the southern extremity of the valley. It was intended that spiral sampling be accomplished at traverse end points to complement the horizontal sampling. However, due to the near IFR conditions, the tower at Meadows Field refused permission to spiral at most locations.

The flight pattern for November 26 is shown in Figure 3.3.10. A summary of parameter concentrations observed on various segments of the pattern is given in Table 3.3.7. Figures 3.3.11 to 3.3.13 show detailed soundings taken over several points near Bakersfield.

At the beginning of the flight (Figure 3.3.11) there were two pollutant layers with tops at about 720 and 1320 m (above ground level). The higher layer apparently represented the carry-over from the previous day. The lower layer contained the pollutants put into the air overnight and in the forenoon. The sounding was made about 7 miles NNW of the Bakersfield urban center and shows high values of SO_2 and b_{scat} in the lowest mixed layer. These pollutants were presumably carried to the spiral location in the easterly drainage flow during the night and early morning.

The next sounding (Figure 3.3.12) was made about 22 miles NNE of the first sounding. Two pollutant layers were again observed. b_{scat} values were similar to the first sounding in each of the two layers, indicating the regional nature of the particulate loading. SO_2 values in the lowest layer, however, were considerably reduced compared to the first sounding in accordance with the local nature of the SO_2 sources.

The third sounding (Figure 3.3.13) was made about 20 miles northwest of the Bakersfield urban area and three hours after the second sounding. By that time the mixing layer had deepened considerably, peak b_{scat} values were somewhat reduced and there was little indication of significant SO_2 concentrations within the mixed layer. The contrast between the b_{scat} profiles of Figure 3.3.13 with Figure 3.3.9 (24 hours previous) is striking and indicates the rapid rate of buildup of pollution in the southern part of the valley when a stabilizing period commences.



SAMPLING ROUTES 26 November 1978

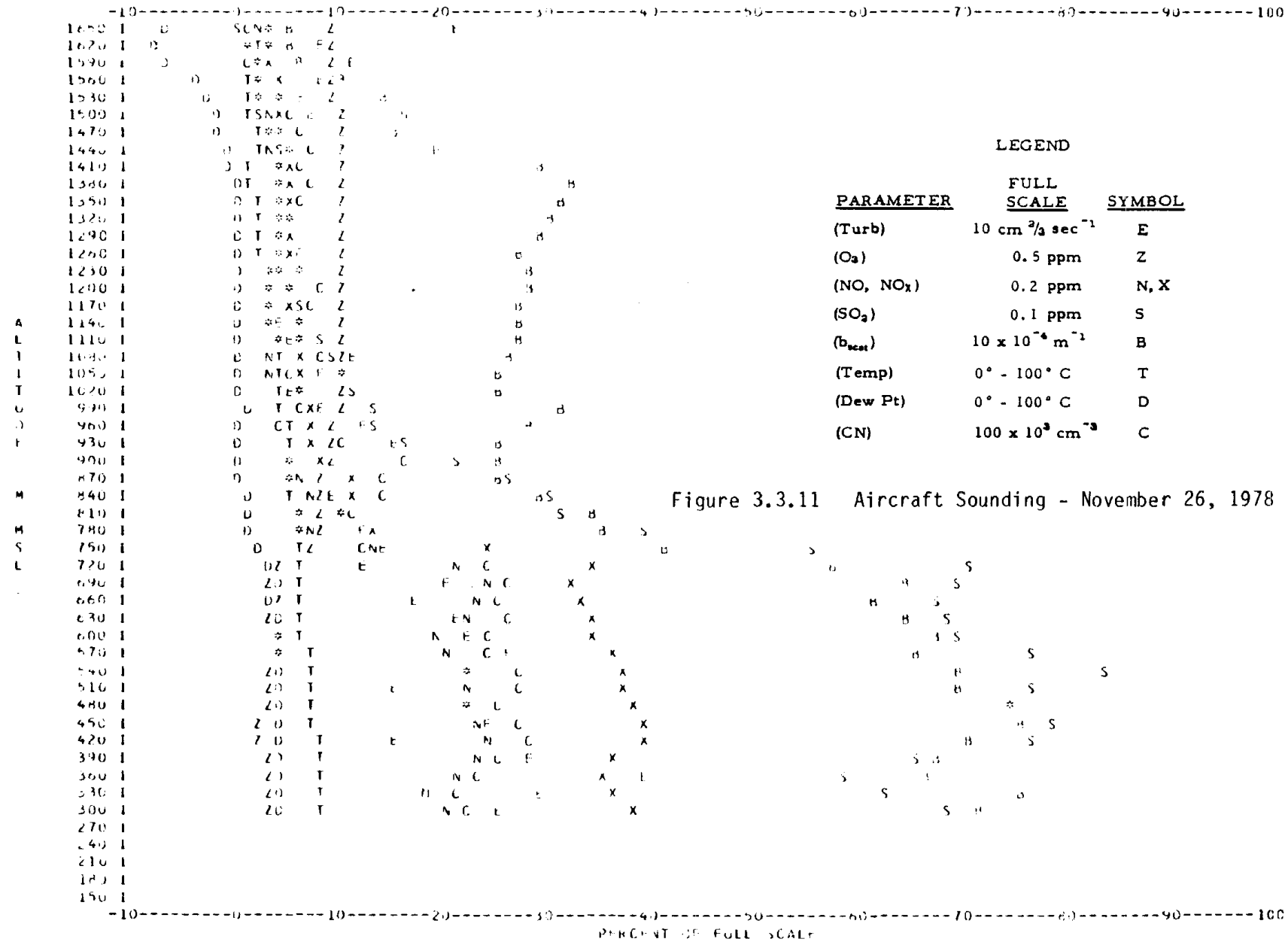
Figure 3.3.10

Table 3.3.7

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 26, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1118	1	38	54	334	820	26	91	28	81	21	51
1146	1-2	27	46	592	880	24	65	33	73	25	60
1203	2	47	54	365	730	6	13	11	23	6	12
1222	2-3	40	48	645	850	10	20	16	24	8	13
1305	3-1	42	51	590	740	4	9	14	26	9	16
1340	1-4	45	51	579	740	4	10	14	23	6	18
1405	4-5	45	51	550	660	2	32	14	27	5	10
1427	5-6	43	49	612	760	1	4	15	34	6	12
1444	6-1	36	45	632	800	1	4	15	34	6	12
1515	7	48	55	409	680	8	10	11	16	6	14

*SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec $^{-1}$	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D
(CN)	100 x 10^3 cm^{-3}	C

Figure 3.3.11 Aircraft Sounding - November 26, 1978

DATE: 11/26/78 ROUTE: [illegible]
CARTRIDGE/PASS: 1657 4
TIME: 12: 3: 5 TO 12:12: 2 MIN. GROUND ELEV.: 219 M(MSL)

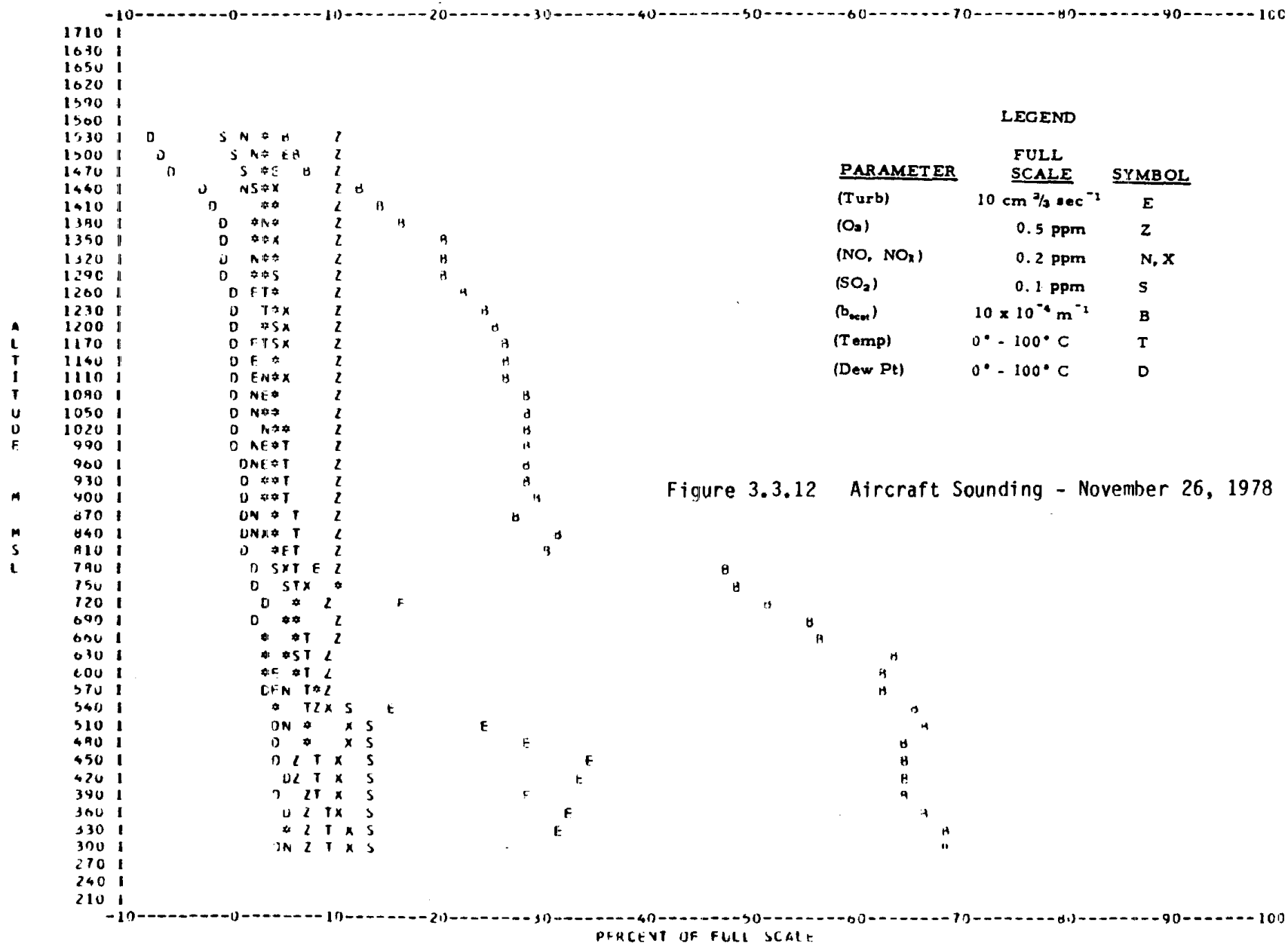


Figure 3.3.12 Aircraft Sounding - November 26, 1978

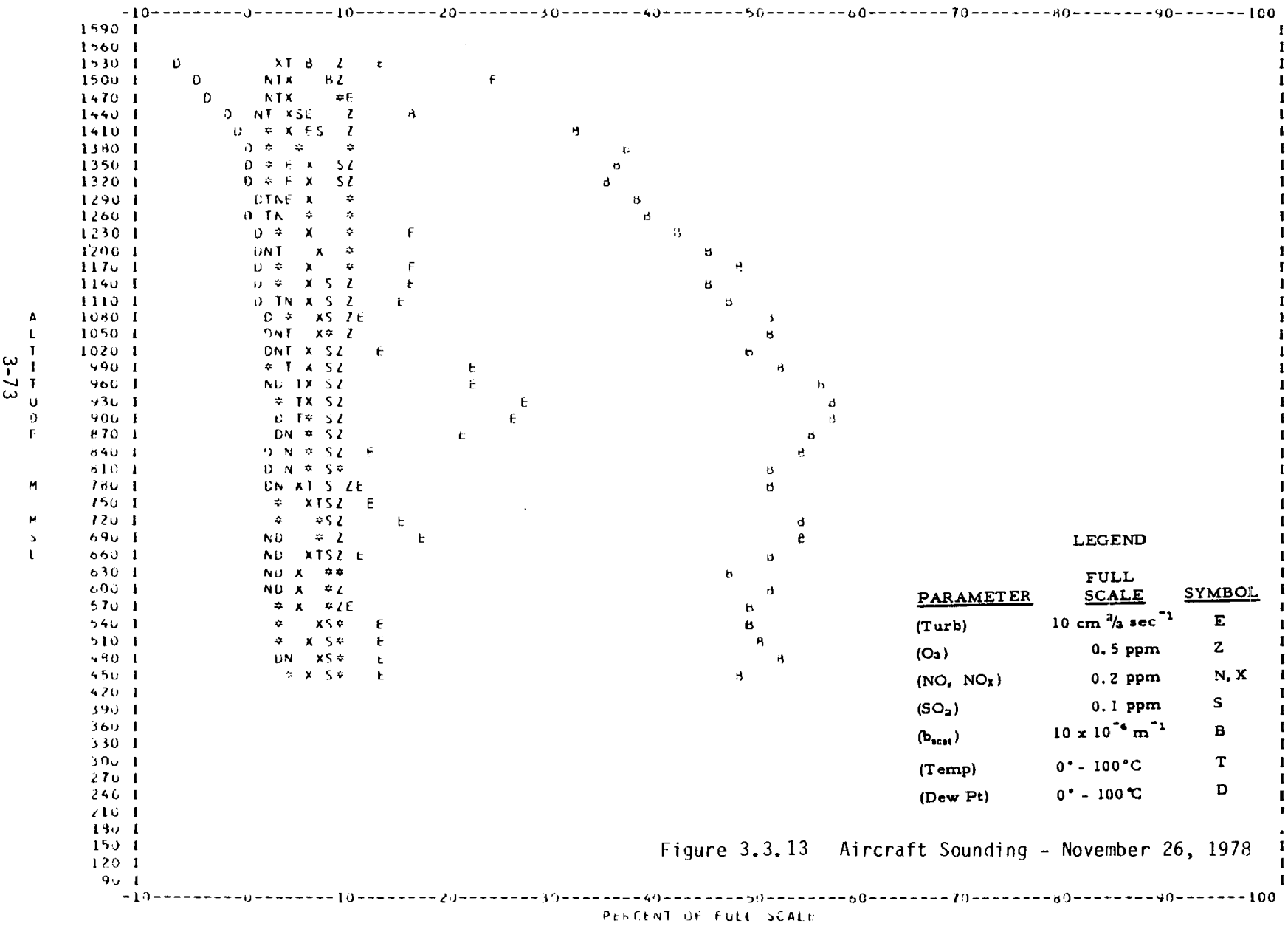


Figure 3.3.13 Aircraft Sounding - November 26, 1978

3.3.3 Tracer Test 3

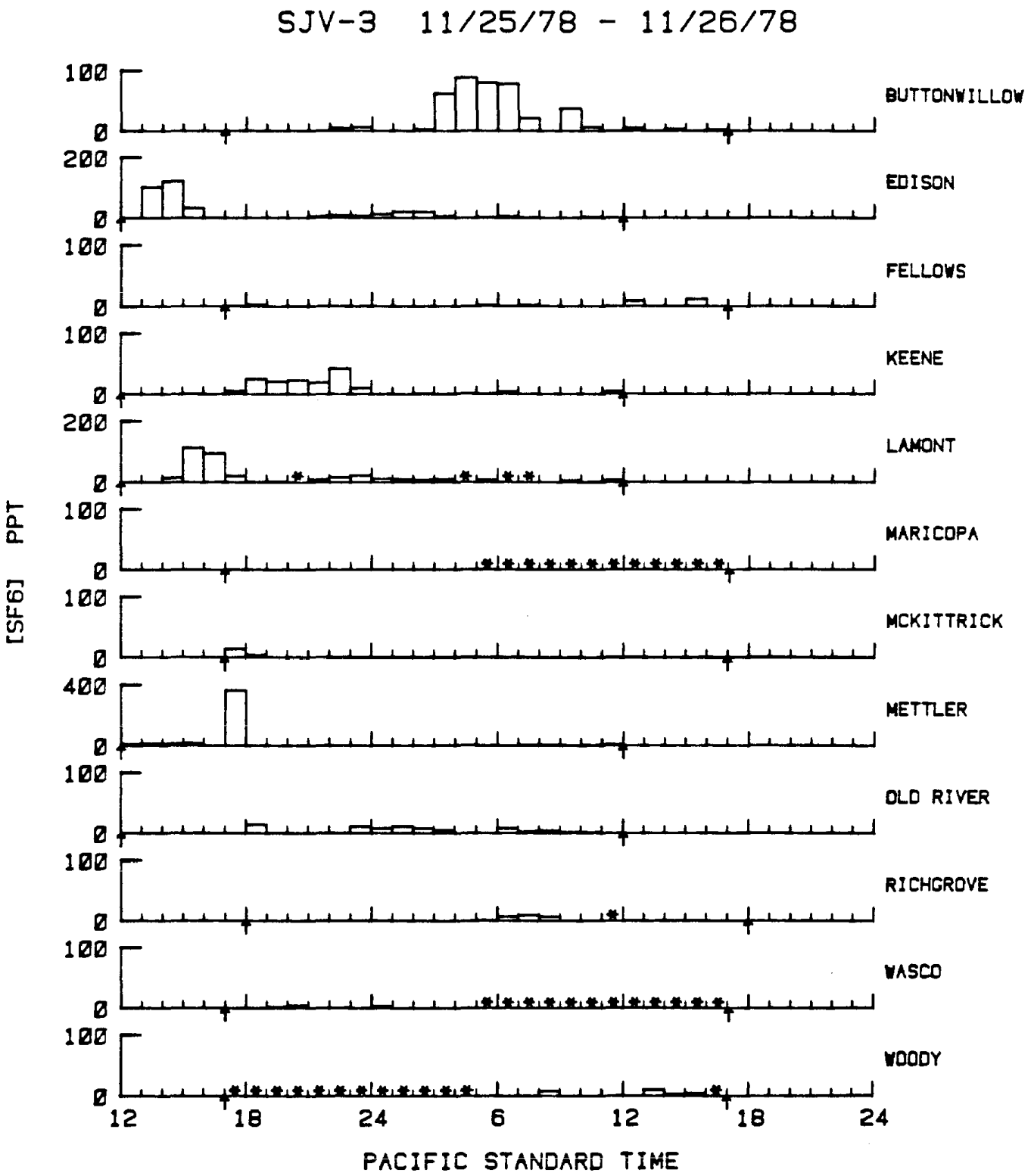
Release Location: Bakersfield, Kern County
Time and Date: 1200-1700 PST, 11/25/78
Amount: 56 pounds of SF_6 per hour
Release conducted during westerly and northwesterly winds

Initial transport southeast

Airplane traverses during mid-afternoon detected the SF_6 south and east of the release site. Most of the airplane sampling was conducted within 15 miles of the release point. As during the second experiment, the width of the sampling interval (typically 1 minute - 2 miles) was too wide to allow good resolution of the SF_6 plume at these distances downwind. The tracer plume, however, lay somewhere between the town of Lamont and Highway 58. An hourly-averaged sampler located at Lamont detected concentrations as high as 110 ppt (290 ppt/lb-mole SF_6 released/hr). The hourly-averaged data at all samplers are contained in Figure 3.3.14. The location of each site is shown in Figure 3.3.15. At Edison, directly east of central Bakersfield, SF_6 concentrations as high as 120 ppt (310 ppt/lb-mole SF_6 released/hr) were detected. The highest concentrations at Lamont were detected between 1500 and 1700 PST, while the highest concentrations at Edison were detected between 1300 and 1500 PST. Beginning about 1800 PST, SF_6 was detected in Keene near Tehachapi Pass. The 6 hour average concentration at Keene between 1800 and midnight was 23 ppt. The maximum SF_6 concentration detected at Keene during this time was 42 ppt (110 ppt/lb-mole SF_6 released/hr) between 2200 and 2300 PST.

Transport westward by evening drainage winds

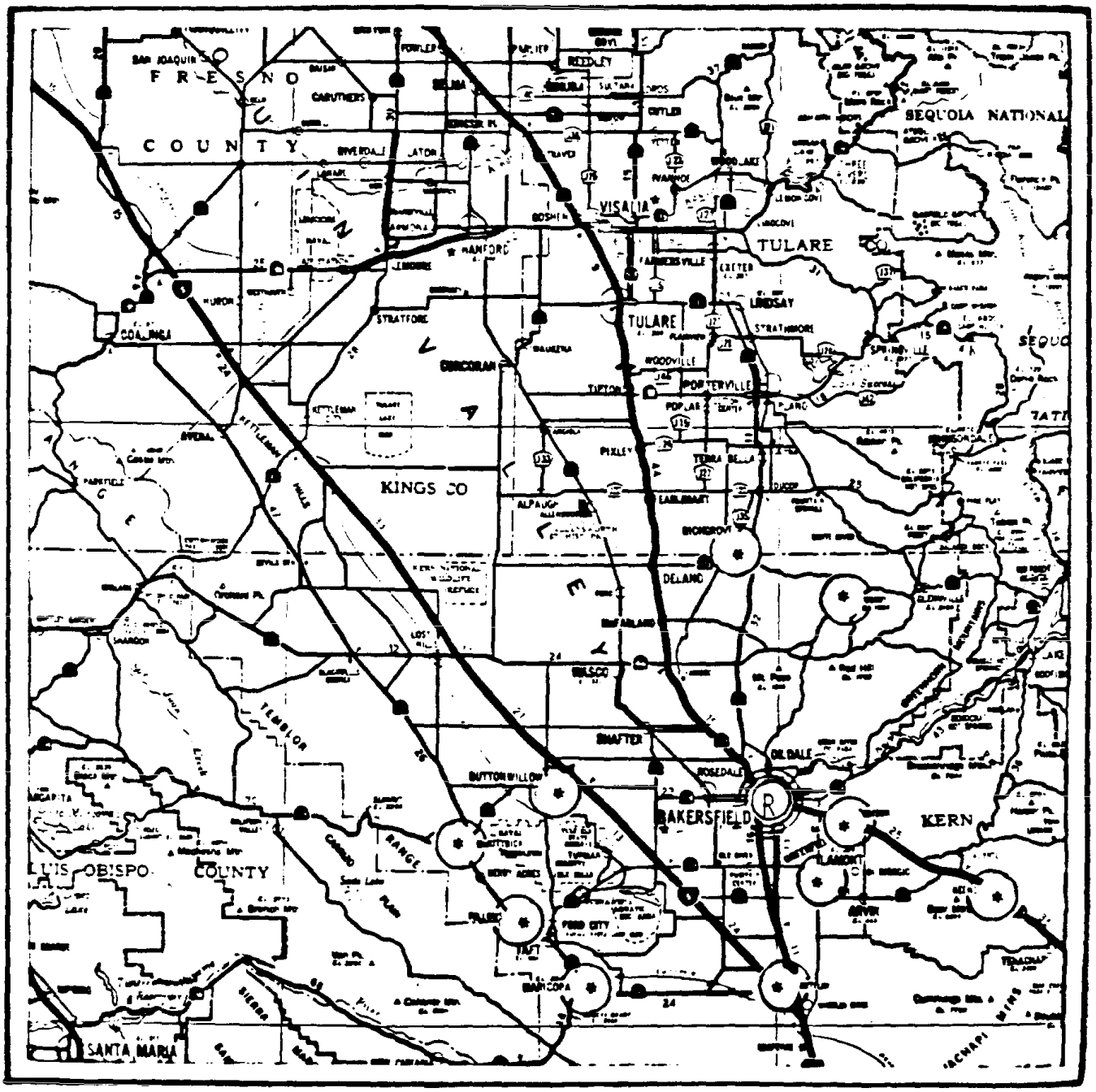
By 1900 PST, easterly drainage winds had developed on the east side of the southern San Joaquin Valley. Corresponding westerly drainage winds developed simultaneously on the west side of the southern valley, giving rise to a convergence zone in the center of the valley. Because SF_6 was first detected at Keene between 1800 and 1900 PST, it is unlikely that a significant amount of the tracer was transported out of the San Joaquin Valley by the surface layer before the wind transition. Automobile traverses at about 1900 PST



RELEASE: 280 LBS SF6 AT BAKERSFIELD
RELEASE TIME: 1200-1700 PST, 11/25/78

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.3.14



INDICATES SAMPLER LOCATIONS

IS THE RELEASE SITE

Figure 3.3.15

showed that the highest concentrations of SF_6 were directly south of Bakersfield. A maximum concentration of 1100 ppt (2900 ppt/lb-mole SF_6 released/hr) was detected about 10 miles south of Bakersfield along Highway 99 during Automobile Traverse 1-1. Later traverses detected high SF_6 concentrations near the intersection of I-5 and Highway 43, near the center of the valley. 520 ppt was detected about midnight near this intersection during Traverse 1-4. During the same traverse, a SF_6 concentration of 550 ppt was detected in southern Bakersfield. During the late night and early morning hours, SF_6 was also detected at Edison and Lamont. A maximum hourly-averaged SF_6 concentration of 20 ppt was detected at Edison between 0100 and 0200 PST, 11/26/78. A maximum hourly-averaged SF_6 concentration of 22 ppt was detected at Lamont between 2300, 11/25/78 and 0000 PST, 11/26/78. At both locations SF_6 concentrations dropped to essentially zero between the arrival of the primary plume during the afternoon and the reversed, drainage plume during the night.

Transport to western side of nighttime convergence zone

SF_6 was transported by the nighttime drainage winds as far west as Buttonwillow where 89 ppt was detected between 0400 and 0500 PST, 11/26/78. Between 0300 and 0700 an average of 77 ppt was detected at Buttonwillow. As described in the meteorological summary, an analysis of the surface winds in the San Joaquin Valley suggested that Buttonwillow would lie on the west side of the convergence zone produced by the drainage winds on each side of the valley. Thus the detection of the high SF_6 levels in Buttonwillow demonstrates that airborne pollutants can be transported to the opposite side of the nighttime convergence zone.

Carryover into the day after the release

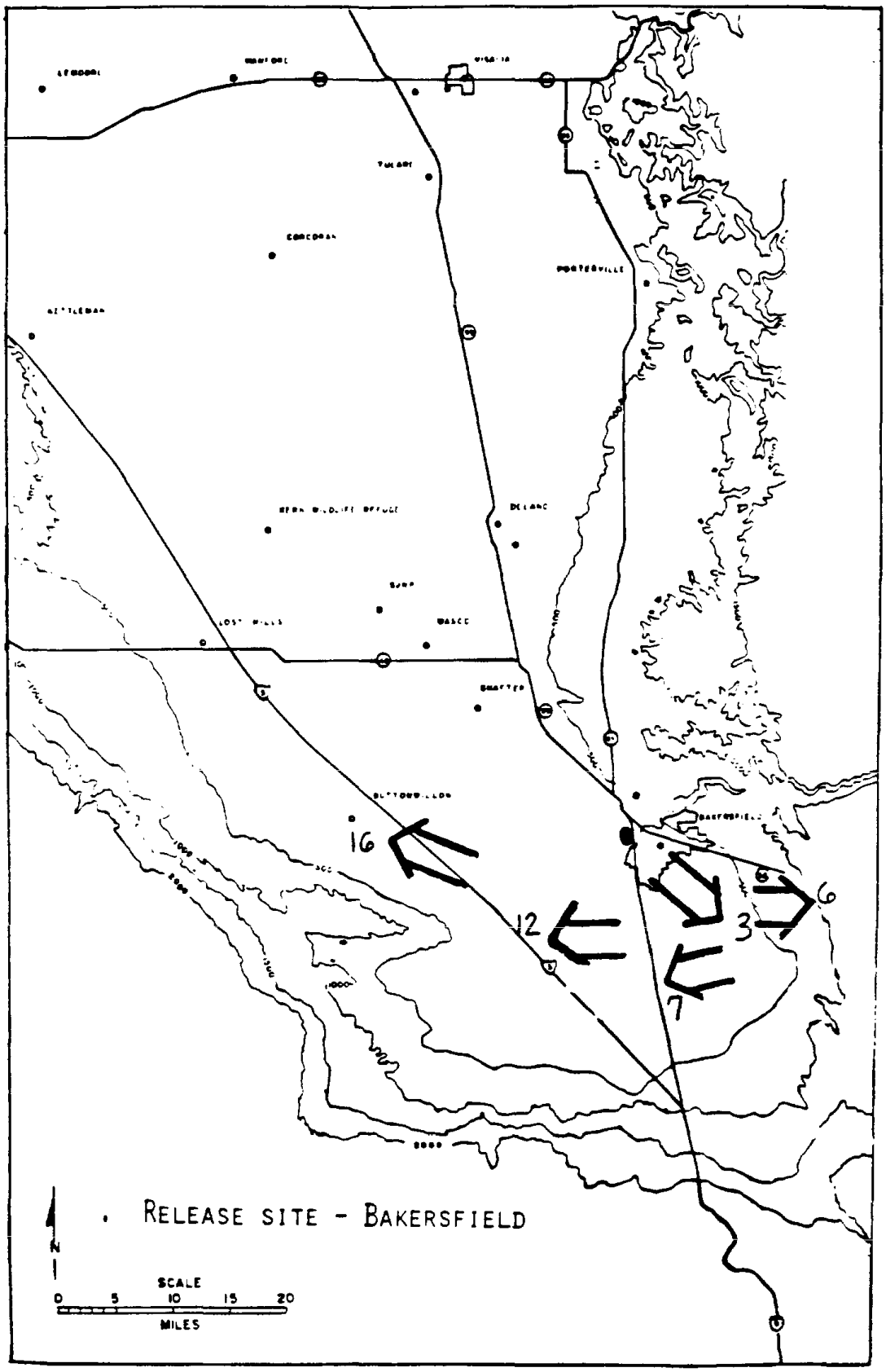
Automobile traverses during the morning following the release (11/26/78) showed that some of the tracer could still be detected in the vicinity of Bakersfield. It was not possible to estimate the total amount of SF_6 transported out of the valley or the fraction of the released material that was transported to the west side of the valley. Winds above 1000 feet elevation,

however, were westerly throughout the night. Since the maximum afternoon mixing height was about 3500 ft (agl) at Bakersfield, there is a possibility that a large amount of SF_6 was transported out of the valley and into the Mojave Desert by the nighttime winds aloft. The highest SF_6 concentration encountered within the valley was 31 ppt at a location about 15 miles south of Bakersfield around 0700 PST, 11/26/78. By mid-afternoon, low but non-zero SF_6 levels could be found over a wide area in the southern San Joaquin Valley. The dilution of the tracer was probably due in large part to the deepening of the mixing layer as the afternoon progressed. By 1600 PST, the mixing depth was in excess of 4000 ft (agl).

Summary

During this experiment, SF_6 released at Bakersfield during an afternoon northwesterly flow was found to impact the entire southern end of the San Joaquin Valley. An overview of the tracer transport paths is presented in Figure 3.3.16. Initially the tracer was transported southeastward. By 1800 PST, the tracer was detected as far east as Keene, in the foothills of the Tehachapi Mountains. By 1900 PST, however, the typical nighttime drainage winds developed, transporting the tracer back towards the center of the valley. Due to the timing of the arrival of the tracer at Keene, probably very little of the tracer was transported into the Mojave Desert by the surface winds. Since the winds aloft were westerly throughout the night of 11/25/78, SF_6 that mixed upward during the day may have been transported into the Mojave Desert.

A westerly drainage wind typically develops on the western half of the valley due to the Coastal Mountains. The juncture of the two drainage flows gives rise to a convergence zone in mid-valley. During this experiment, the tracer was clearly transported to the western side of the nighttime "convergence zone," demonstrating that transport of emissions can occur from the east side to the west side of the "convergence zone" within the San Joaquin Valley.



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (1200 PST, 11/25/78)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.3.16

3.4 Test 4 29-30 November 1978 - Elk Hills Release (1200-1700 PST)

3.4.1 Meteorology

General

The major synoptic feature during this test period was the Pacific High centered about 300 miles west of San Francisco (Figure 2.2.1); supported by strong ridging aloft off the west coast. As a result, the Pacific storm track was well to the north of California before turning southeast toward the Great Basin region. A stable air mass resided over central California. Weak pressure gradients and weak synoptic scale flow were present in the region of interest. Temperatures aloft as represented by the Vandenberg 850 mb observation on Figure 3.4.1 had been steadily increasing over the previous several days, peaking on the morning of the 30th at 13.5°C or 2°C above the five-year average. Sky conditions were mostly clear over the southern San Joaquin Valley with only occasional high scattered clouds. Visibilities were restricted from 2-1/2 to 5 miles due to smoke and haze. The maximum surface temperature recorded at Bakersfield was 69°F and 71°F on the 29th and 30th, respectively, above normal for that time of the year.

Transport Winds

The surface winds in the Elk Hills region, tabulated in Table 3.4.1 were extremely light throughout the experimental period; generally less than 1 m/sec. As depicted by the surface streamlines constructed from the 1300 PST observed winds (Figure 3.4.2), the flow was directed very slowly towards the westside hills during the afternoon. By 1700 PST a drainage flow pattern (shown here on Figure 3.4.3 for 2200 PST) was established at the surface and persisted throughout the evening of the 29th and the morning of the 30th. This flow changed into its daytime northwesterly flow by 1000 PST as illustrated in Figure 3.4.4. The winds at Elk Hills (Table 3.4.1) show characteristically downslope (drainage) flow beginning at 1700 PST and continuing until mid-morning. On the other side of the valley, Bakersfield shows similar drainage flow (from the east) from 1800 PST until 0900 PST the next morning. The convergence zone between these flows is shown as a dashed line in Figure 3.4.3. The zone may, in reality, not be as sharp as indicated and its location may even vary with height above ground.

WEDNESDAY, NOVEMBER 29, 1978

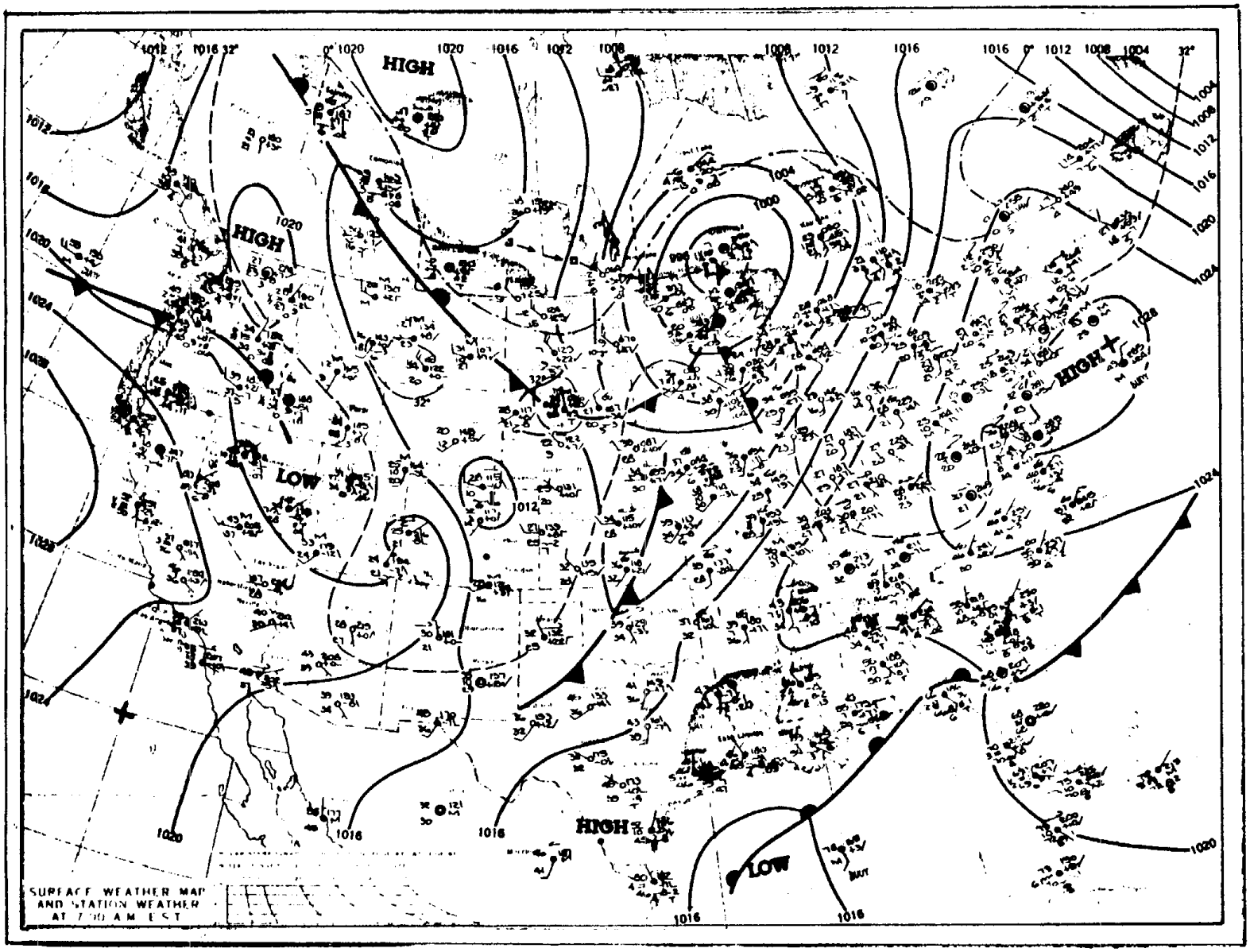


Figure 3.4.1 Surface Weather Map - November 29, 1978

Table 3.4.1

SURFACE WINDS - ELK HILLS, BAKERSFIELD
NOVEMBER 29-30, 1978

Date	Time (PST)	Elk Hills	Bakersfield Airport
11-29	12		
	13		070°/1.6 m/s
	14	Calm	340 /2.1
	15	Calm	300 /4.1
	16	102°/0.2 m/s	280 /3.1
	17	250 /0.1	240 /2.1
	18	230 /0.2	010 /2.1
	19	248 /0.9	Calm
	20	248 /1.0	060 /2.6
	21	222 /0.8	100 /2.1
	22	238 /0.4	100 /2.1
	23	240 /0.2	090 /2.1
11-30	00	229 /0.3	090 /2.1
	01	260 /0.8	100 /2.6
	02	261 /0.5	Calm
	03	273 /0.7	100 /2.6
	04	Calm	100 /3.1
	05	244 /0.4	120 /2.6
	06	261 /0.3	100 /2.1
	07	235 /0.4	090 /2.6
	08	Calm	Calm
	09	Calm	250 /1.5
	10	Calm	260 /2.1
	11	Calm	140 /2.6
	12	046 /0.2	250 /2.6

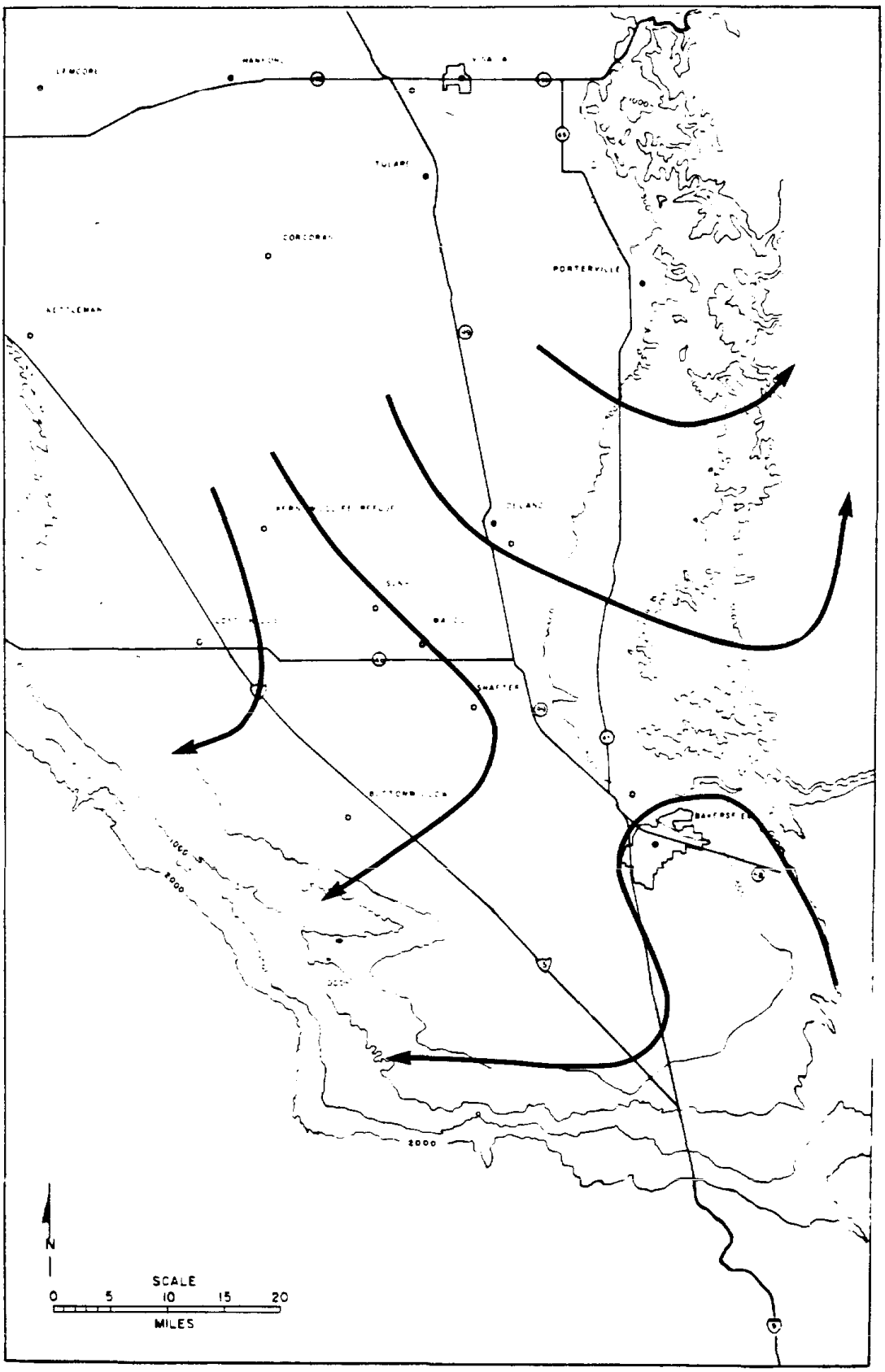


Figure 3.4.2 Surface Streamlines - 29 November 1978 (13 PST)

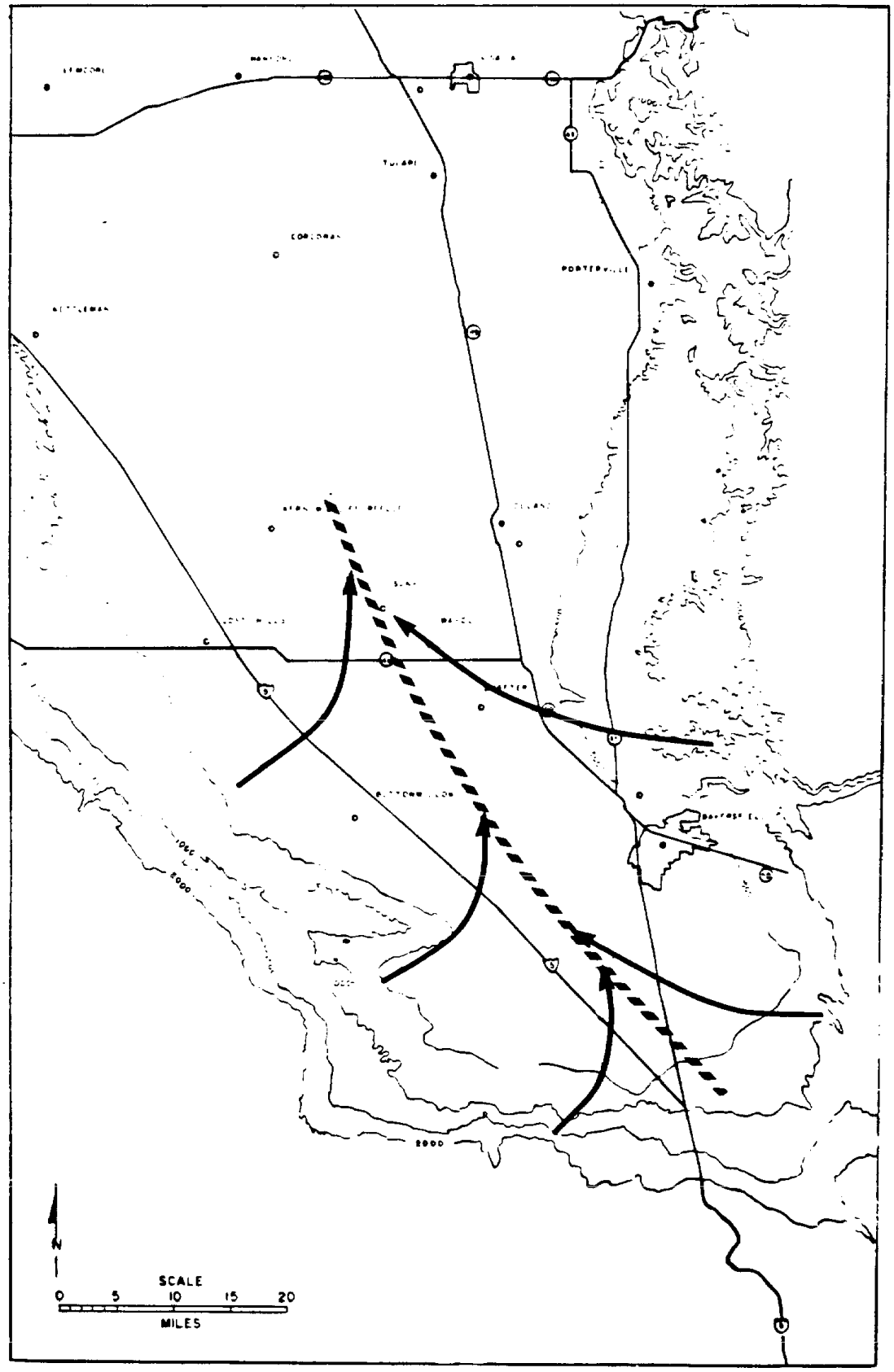


Figure 3.4.3 Surface Streamlines - 29 November 1978 (22 PST)

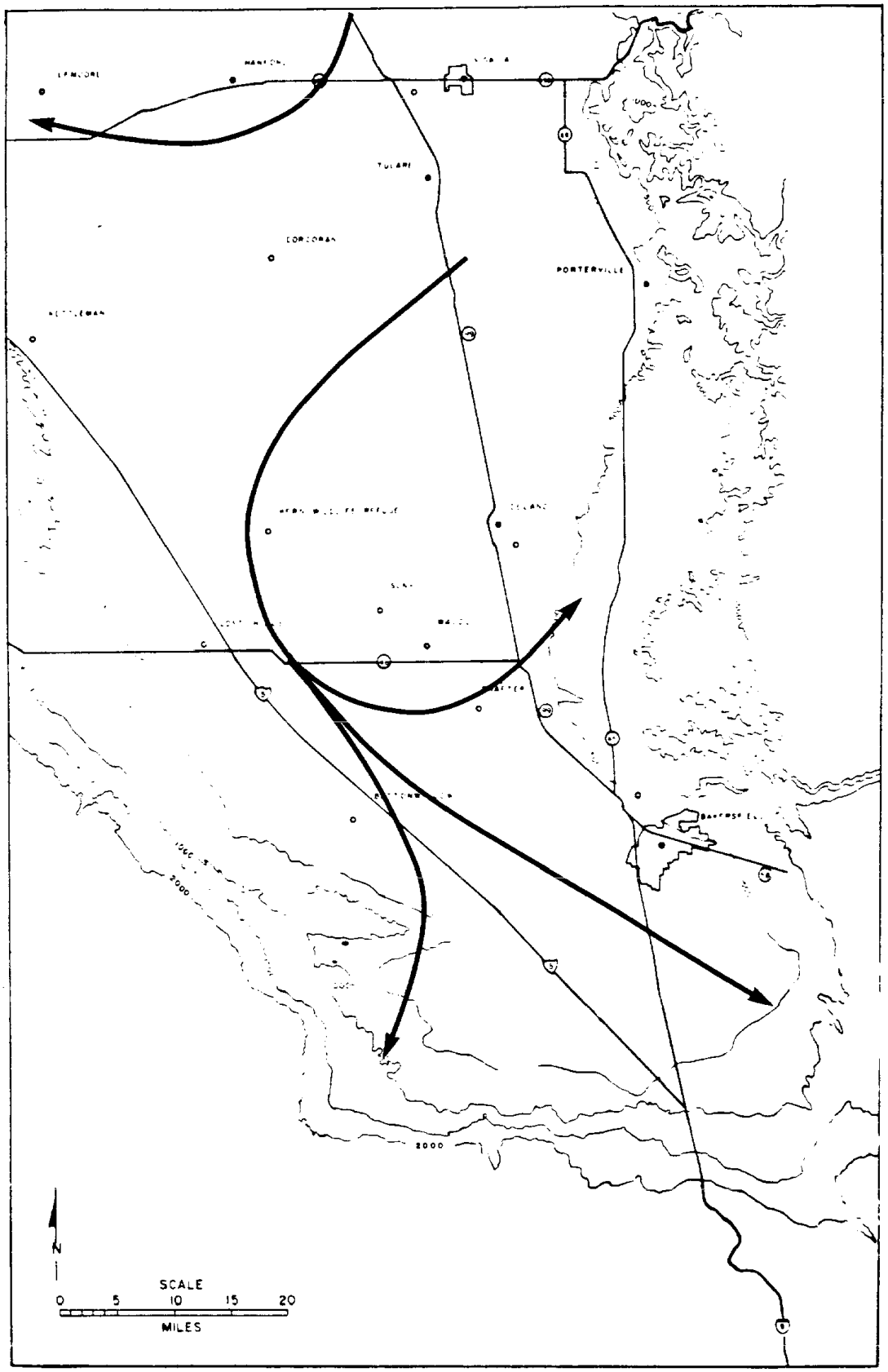


Figure 3.4.4 Surface Streamlines - 30 November 1978 (10 PST)

The 1000-foot winds at Elk Hills and Bakersfield are given in Table 3.4.2. It is to be noted that the Elk Hills winds were very light throughout the 24 hours after release had started but were consistently from the southeast with a few exceptions These data, compared to those in Table 3.4.1, indicate the shallow nature of the nocturnal drainage flow (less than 1000 feet thick). Bakersfield shows generally northwest winds through 19 PST followed by easterly winds at 05 PST.

Table 3.4.2

1000 FOOT WINDS
NOVEMBER 29-30, 1978

Date	Time (PST)	Elk Hills	Bakersfield
11-29	11		228°/1.6 m/s
	13	149 /0.6 m/s	321 /0.7
	14	343 /0.5	
	15	127 /0.6	318 /3.7
	16	86 /1.5	
	17	117 /2.0	188 /0.5
	18	75 /1.9	
	19	121 /1.6	289 /0.3
	21	331 /0.6	
11-30	00	117 /0.4	
	03	116 /0.7	
	05		100 /1.8
	06	155 /1.0	
	07	120 /0.5	
	08	175 /0.4	
	09	130 /1.0	
	11	231 /0.4	

Early in the release period the low-level winds at Elk Hills appear to have had a more southerly component resulting in some tracer material being carried to the north and northwest. Thereafter, it appeared to have been tranported to the northeast (see Figures 3.4.3 and 3.4.4). The bulk of the tracer, however, was carried upslope to the west of the release site. Since the end of the release coincided with the beginning of the downslope flow much of this material drained back down the slopes into the southern end of the valley and eastward.

Mixing Layer Heights

Mixing layer heights were measured by the aircraft on November 28, 29 and 30 (Table 3.4.3). Heights ranged from about 500-800 m during the entire three-day period. This consistency coincides with relatively warm temperatures at 850 mb culminating in a peak temperature on November 30.

Table 3.4.3

AIRCRAFT MIXING HEIGHTS

Time (PST)	Location*	Mixing Height (agl) (m)
	November 28, 1978	
0823	4 NNW BFL AP	510
1039	4 NNW BFL AP	450
1223	4 NNW BFL AP	570
	November 29, 1978	
1422	Elk Hills AP	630
1531	19 SSE Elk Hills	840
1657	22 SE Elk Hills	840
	November 30, 1978	
1521	4 NNW BFL AP	770
1640	12 NNW BFL AP	800

* Distances in miles

3.4.2 Air Quality

Surface Air Quality

Maximum hourly ozone concentration in the valley on November 29 was 0.07 ppm at Fountain Springs. An appreciable part of the valley experienced levels of 0.05 ppm or more. These are shown in Figure 3.4.5.

Table 3.4.4 gives the maximum concentrations of other parameters observed in the valley on November 29.

Table 3.4.4

MAXIMUM HOURLY CONCENTRATIONS
NOVEMBER 29, 1978

Location	CO (ppm)	SO_2 (ppm)	NO_x (ppm)
Fresno-Olive	18		
Oildale		0.10	
Fresno-Olive			0.88
Reedley			0.51
Radome		0.03	0.68
Lost Hills		0.03	0.52

Surface visibilities at 1300 PST are given in Table 3.4.5 for a number of airport stations in the valley.

Table 3.4.5

1300 PST VISIBILITIES
NOVEMBER 29, 1978

Station	Visibility (miles)
Sacramento	2 HK
Stockton	3 HK
Modesto	3 H
Crow's Landing	3 H
Merced	1-7/8 HK
Fresno	7/8 H
Lemoore NAS	2-1/4 H
Visalia	2 H
Bakersfield	7/8 H

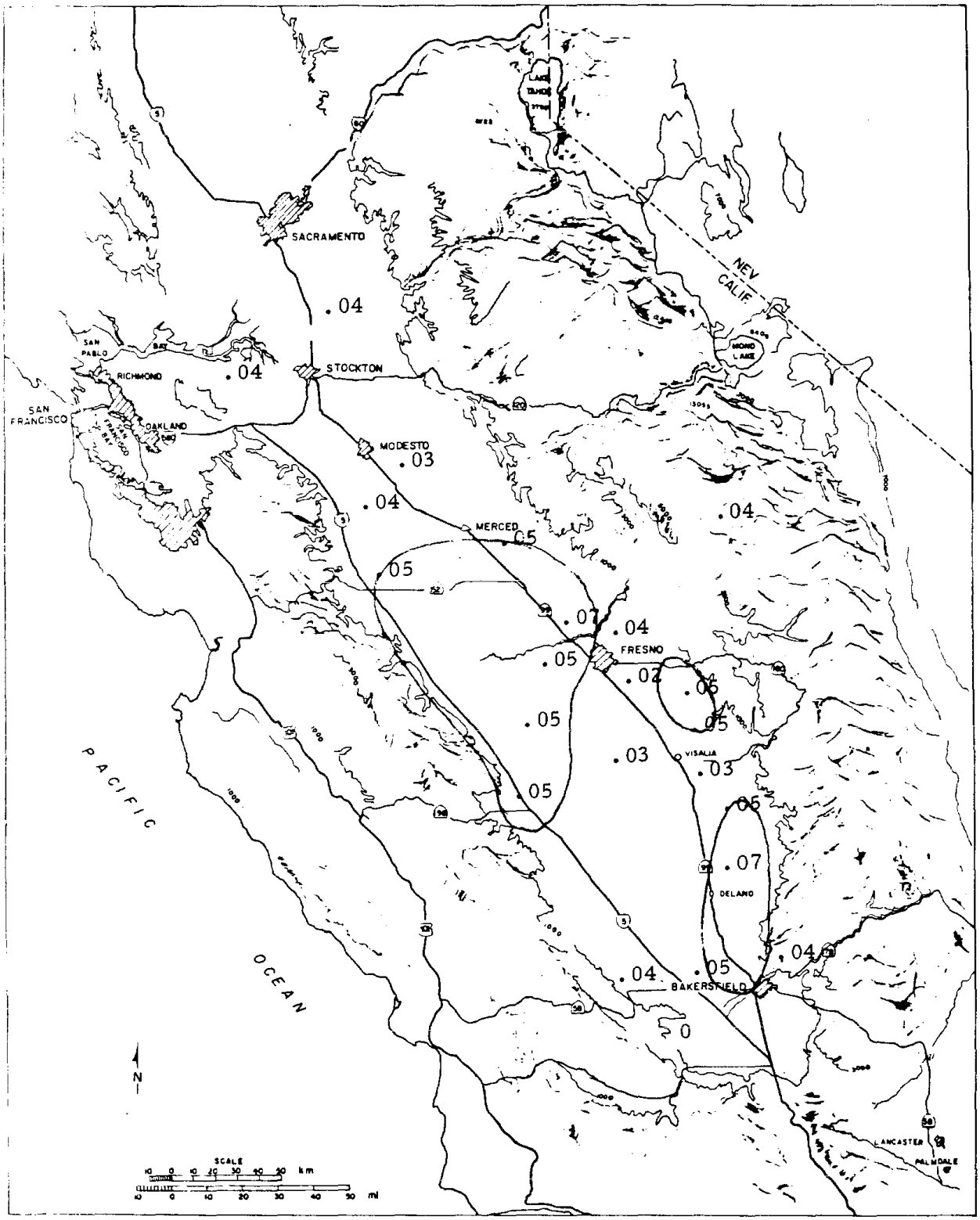


Figure 3.4.5 Maximum Hourly Ozone Concentrations (ppm) - November 29, 1978

Visibilities throughout the valley were three miles or less, restricted by smoke and haze. No fog was reported at any station.

Aircraft Sampling - 28 November 1978

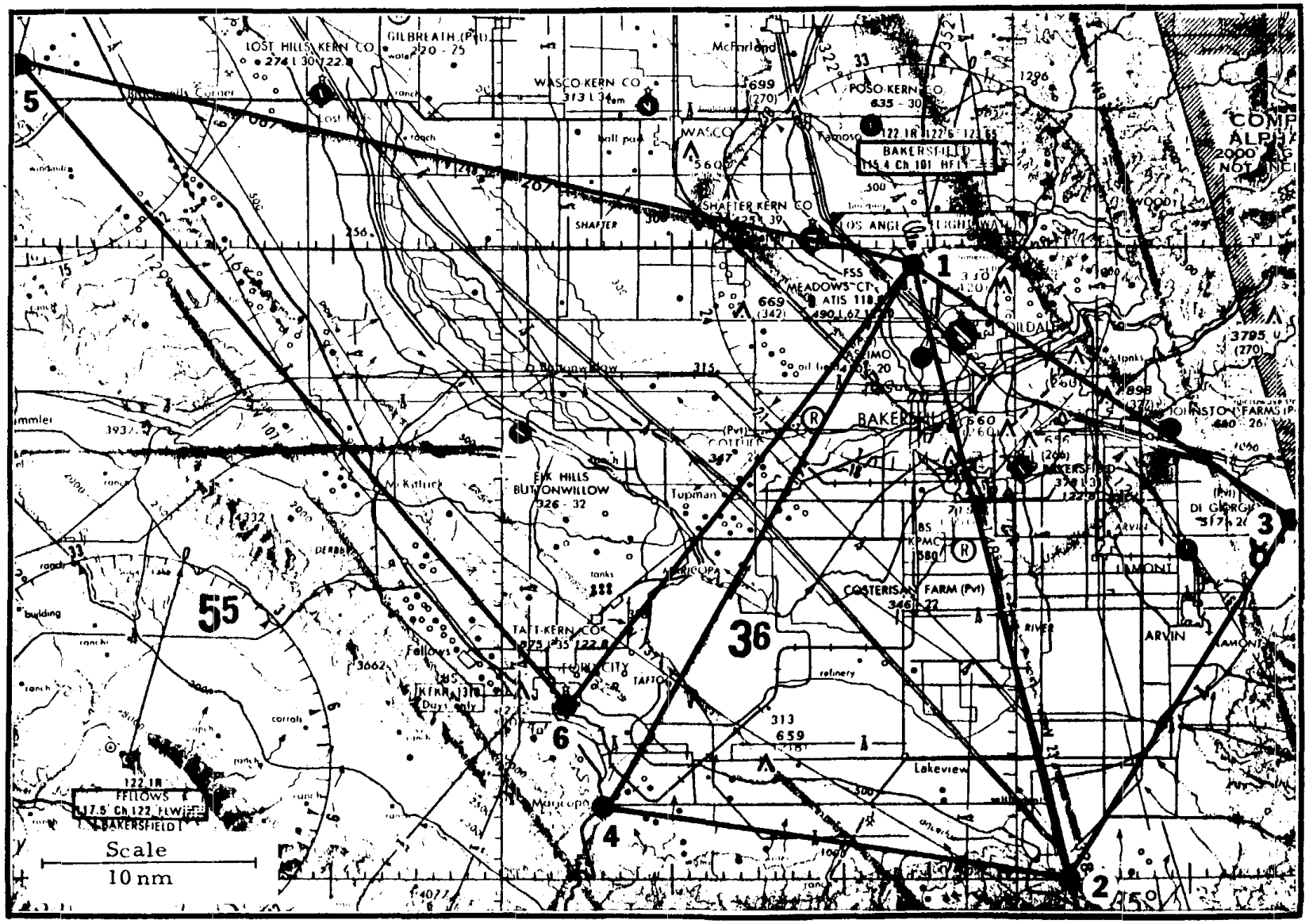
The primary objective of this sampling mission was to determine the distribution of pollutants in the southern San Joaquin Valley under stable atmospheric conditions with little air movement. The flight plan was designed to sample over the oil fields on the west side of the valley from the Lost Hills area in the north to Maricopa in the south. Several traverses were flown on a radial from the Bakersfield VOR and along the southern edge of the valley such that all portions of the southern San Joaquin Valley were sampled. Spirals over the VOR were flown at the start, in the middle, and at the end of sampling to measure atmospheric stability and temporal changes in the vertical during the flight.

The flight pattern for November 28 is shown in Figure 3.4.6. A summary of concentrations of various parameters observed during the flight is given in Table 3.4.6. Detailed soundings at Bakersfield are included as Figure 3.4.7 to 3.4.9.

The sounding at 0823 PST at Bakersfield (Figure 3.4.7) shows a shallow surface mixing layer (depth 390 m above ground level) with large SO_2 and b_{scat} values. Two other layers were evident in the sounding, one centered at 450 m and the other at 750 m (above ground level). Both upper layers were apparent in SO_2 and b_{scat} values. The top of the highest layer (960 m above ground level) probably represents the highest mixing level reached during the previous day.

The 1034 PST sounding, made at the same location continues to show a surface layer (top 450 m above ground level) with large b_{scat} values but with reduced SO_2 concentrations, compared to the previous sounding. Two elevated layers were also present in this souunding with tops of 750 m and 1050 m (above ground level). b_{scat} values in the highest layer were considerably reduced from the previous sounding.

At 1223 PST the sounding again shows several layers aloft. The surface layer extends to 600 m (above ground level) but contains two imbedded layers (plumes) centered at 360 m and 510 m (above grouund level). Concentrations at higher levels continued to decrease but there remains evidence of the top of an old mixed layer at 930 m (above ground level).



SAMPLING ROUTES 28 November 1978

Figure 3.4.6

Table 3.4.6

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 28, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
0823	1	34	43	216	930	25	176	16	74	-	-
0843	1-2	39	54	824	1240	36	570	23	121	27	115
0905	2-3	44	53	761	1000	2	6	12	17	8	13
0922	3-1	33	42	899	1330	27	260	23	66		
0941	1-4	47	56	760	1090	7	104	15	53	7	25
1005	4-2	36	44	357	740	21	41	20	45	9	21
1022	2-1	44	56	636	1010	16	36	20	37	12	22
1039	1	41	47	218	1020	5	27	13	47	9	27
1105	1-5	45	54	577	970	13	43	18	48	10	22
1135	5-6	38	48	572	950	12	77	27	57	10	23
1204	6-1	46	53	466	1801	10	41	14	33	7	14
1223	1										

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 11/28/78 ROUT : OVER POINT 1
CARTRIDGE/PASS: 1677 1
TIME: 8:23:48 TO 8:31:46 MIN. GROUND ELEV.: 91 M(MSL)

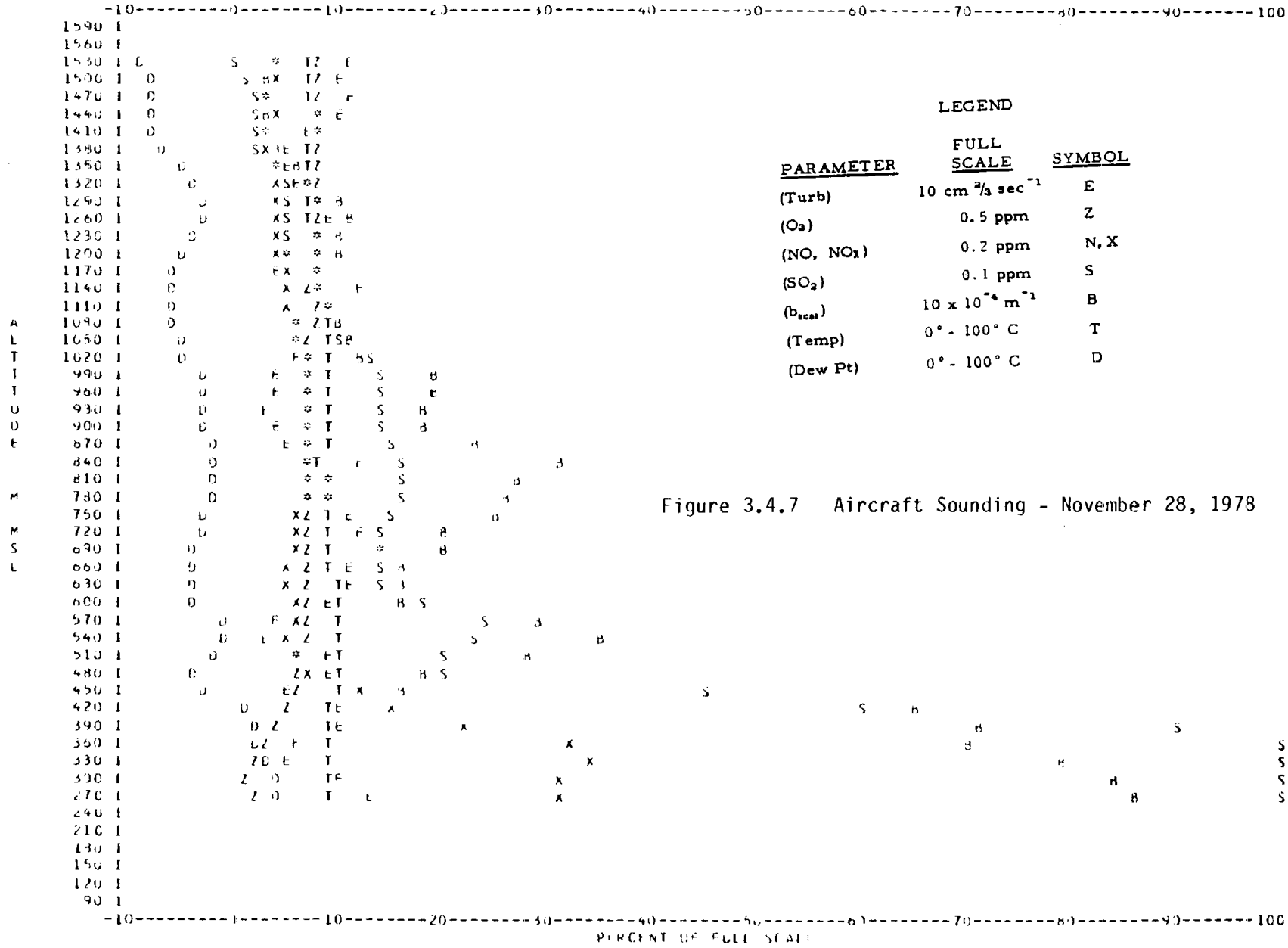
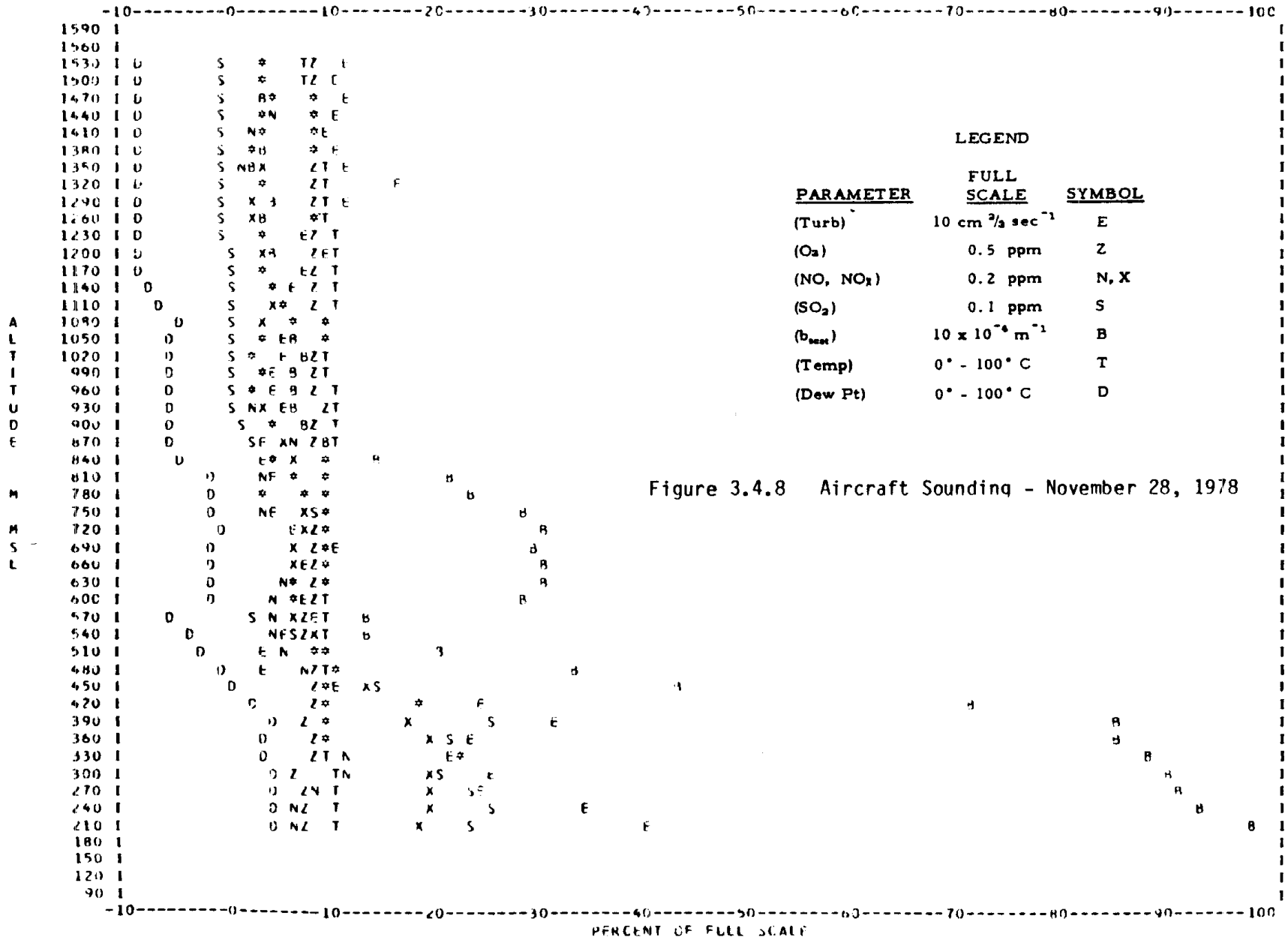


Figure 3.4.7 Aircraft Sounding - November 28, 1978

DATE: 11/28/78
CARTRIDGE/PASS: 1677 8
TIME: 10:39:39 TO 10:47:28

ROUTE: OVER POINT 1
MIN. GROUND ELEV.: 91 M(MSL)

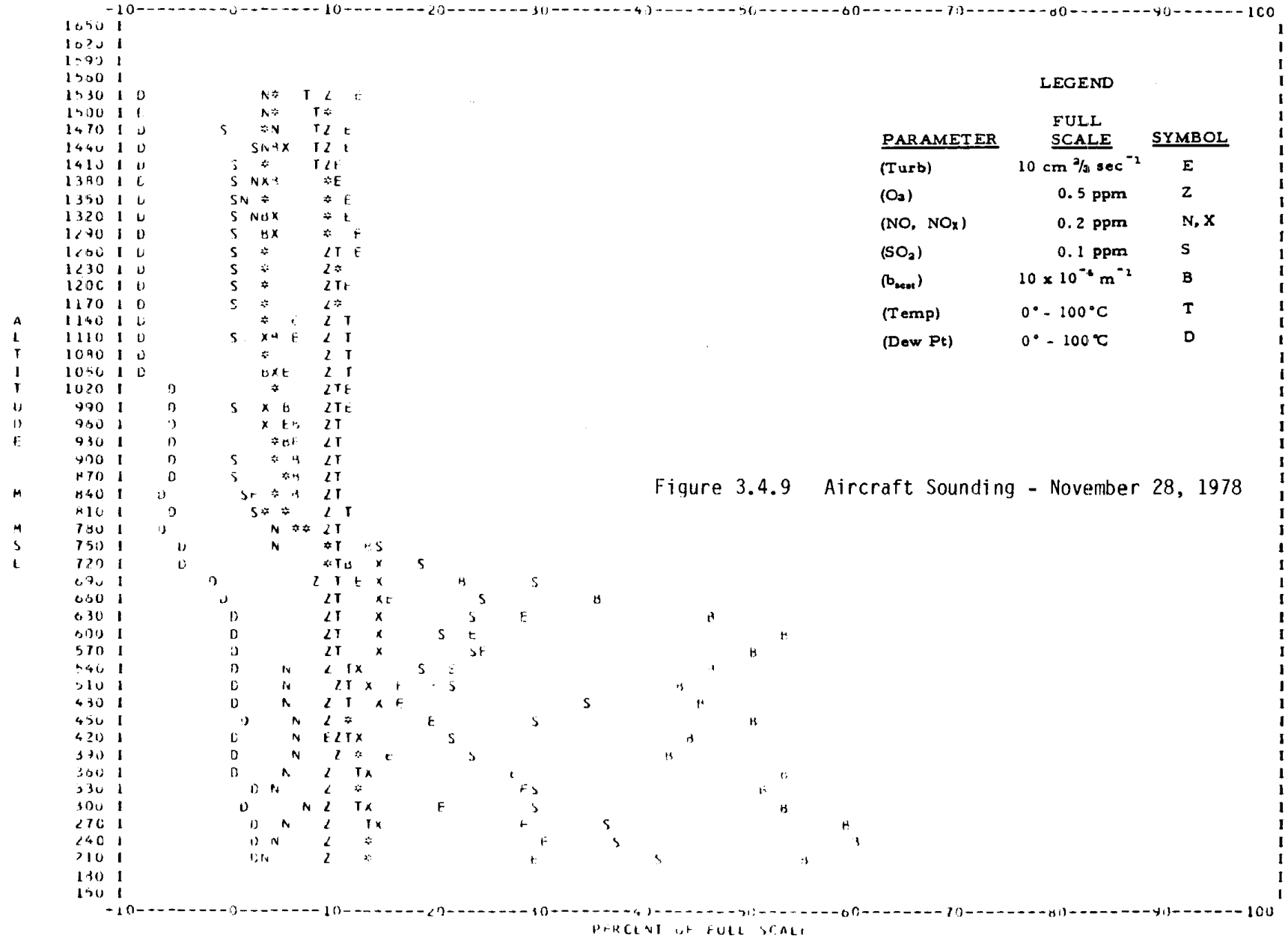


LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-6} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.4.8 Aircraft Sounding - November 28, 1978

DATE: 11/28/78 RCUTE: LV-P POINT 1
CARTRIDGE/PASS: 1557 13
TIME: 12:23:43 TO 12:31: 8 MIN. GROUND ELEV.: 252 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec $^{-1}$	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m $^{-1}$	B
(Temp)	0° - 100°C	T
(Dew Pt)	0° - 100°C	D

Figure 3.4.9 Aircraft Sounding - November 28, 1978

Sources of significant concentrations of SO_2 and NO_x were identified on the traverse near Highway 99 through Bakersfield. The Bakersfield source, which appeared to be a refinery, produced SO_2 concentrations in excess of 500 ppb and NO_x in excess of 120 ppb. Levels of SO_2 as high as 260 ppb were measured over the oil fields. On the west side, significant sources of SO_2 and NO_x were observed from the North Antelope Oil Field southeast to Cymric Oil Field (north of McKittrick). Maximum concentrations of SO_2 and NO_x measured were 77 ppb and 57 ppb, respectively. Additional sources of SO_2 and NO_x were identified in the Taft and Maricopa areas.

Aircraft Sampling - 29 November 1978

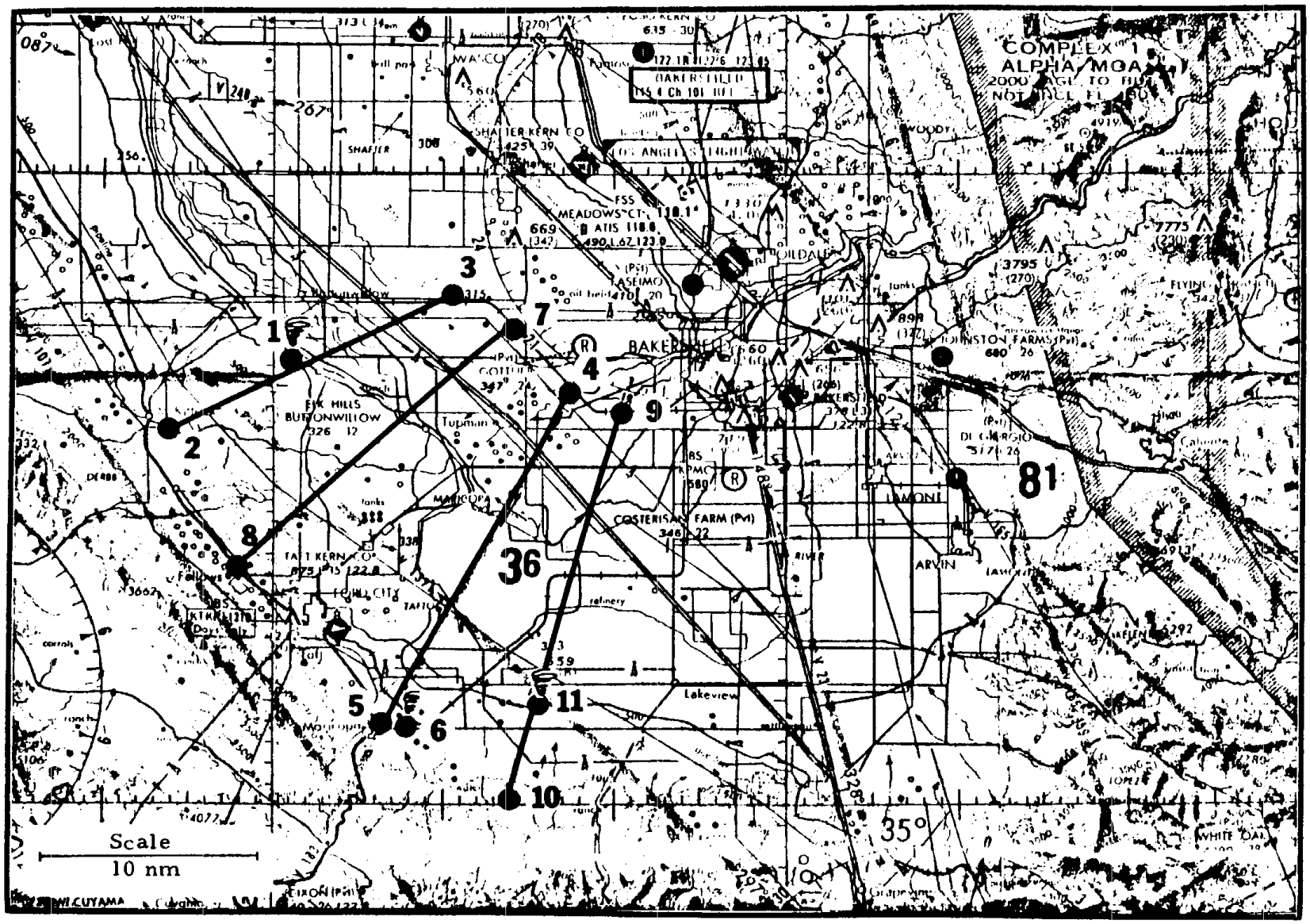
In conjunction with a tracer release from Valley Acres, a series of traverses were flown to determine (1) the distribution of effluent from the west valley oil fields and (2) to provide aerial coverage of tracer dispersion. Due to the light and variable nature of the winds reported from pibal observations at the release site, the sampling was designed to provide coverage over the entire southwestern portion of the valley south of Elk Hills. The traverses were flown at two altitudes within the mixing layer and spirals were flown at several locations to determine atmospheric stability.

The flight pattern on November 29 is shown in Figure 3.4.10. A table giving summaries of pollutant concentrations observed in various portions of the pattern is given in Table 3.4.7. Detailed soundings taken on the west side of the valley are shown in Figures 3.4.11 to 3.4.13.

The sounding made near Buttonwillow at 1422 (Figure 3.4.11) shows a surface layer mixed upward to 660 m (above ground level). The layer was primarily characterized by large b_{scat} values but also shows slightly elevated ozone concentrations.

By 1530 PST (Figure 3.4.12) the surface mixed layer extended to 870 m (above ground level) and showed slight decreases in b_{scat} values and slight increases in ozone compared to the previous sounding. Maximum ozone concentrations were 0.08 ppm.

The sounding at 1657 (Figure 3.4.13) was made to the east of Maricopa. The surface mixed layer extended to 840 m. Ozone and b_{scat} values were similar to the previous sounding, indicating regional or well-mixed sources of these parameters. SO_2 and NO_x levels were relatively low.



SAMPLING ROUTES 29 November 1978

Figure 3.4.10

Table 3.4.7

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 29, 1978

		O_3		b_{scat}		SO_2*		NO_x		NO	
Start Time (PST)	Location (Point)	Mean (ppb)	Max (ppb)	Mean ($x10^{-6}m^{-1}$)	Max	Mean (ppb)	Max (ppb)	Mean (ppb)	Max (ppb)	Mean (ppb)	Max (ppb)
1422	1	59	76	355	940	1	18	16	31	7	15
1447	2-3	74	82	699	850	1	7	24	33	7	13
1459	3-2	75	82	755	900	1	7	22	34	7	11
1518	4-5	72	84	648	830	1	14	22	34	5	11
1531	6	61	83	371	830	0	9	17	34	6	28
1551	5-4	72	84	652	800	2	29	23	36	5	11
1607	7-8	71	78	622	780	3	15	23	35	3	7
1621	8-7	71	80	660	840	1	7	22	33	3	8
1638	9-10	69	78	594	790	-1	1	22	35	4	8
1657	11	61	83	351	780	2	19	17	29	4	9
1723	10-9	73	84	637	810	1	7	23	34	5	10

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

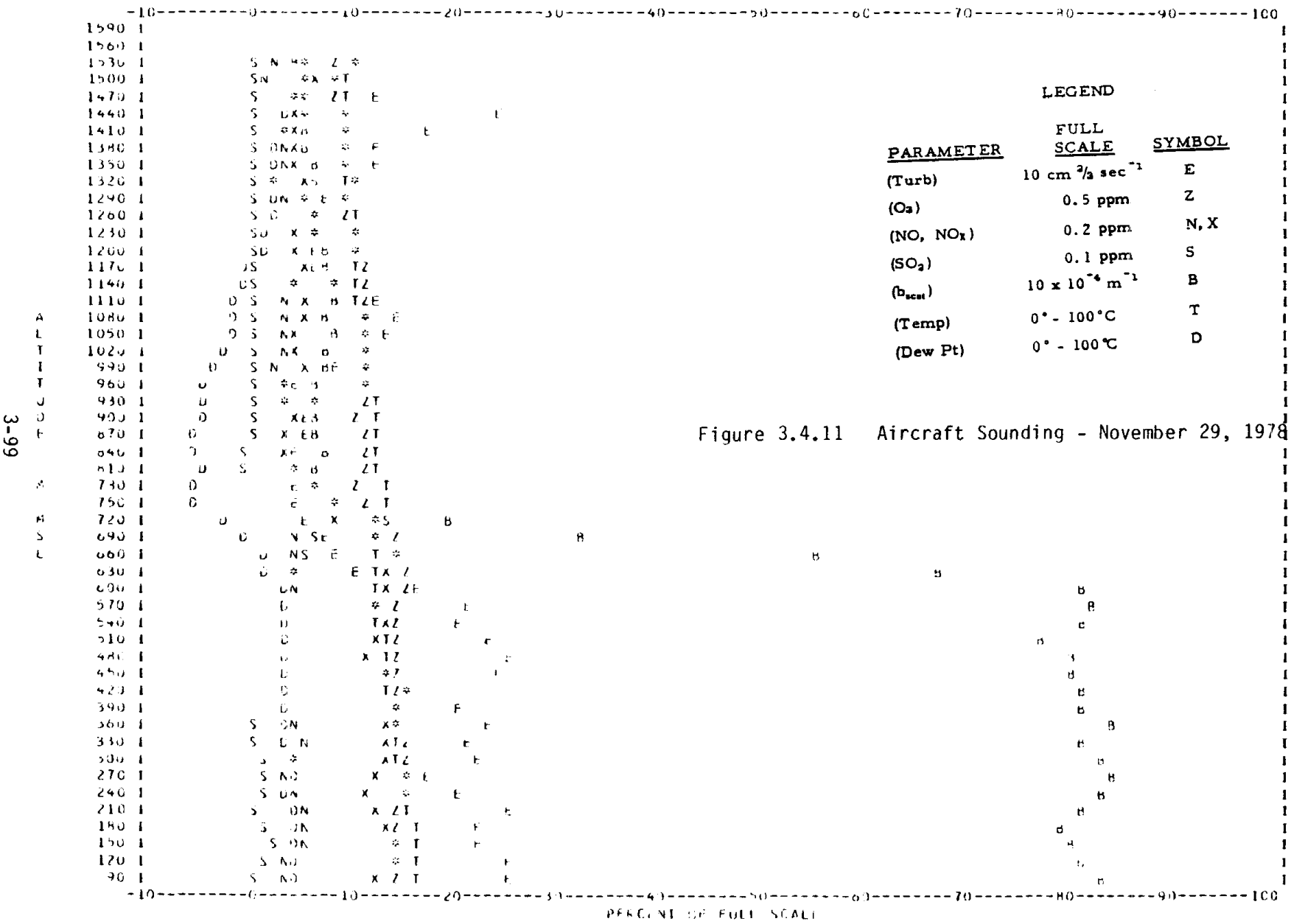


Figure 3.4.11 Aircraft Sounding - November 29, 1978

DATE: 11/29/78 ROUTE: [illegible] POINT 6
CARTRIDGE/PASS: 1697 5
TIME: 15:21:54 TO 15:41: 3 MIN. GROUND ELEV.: 91 M(MSL)

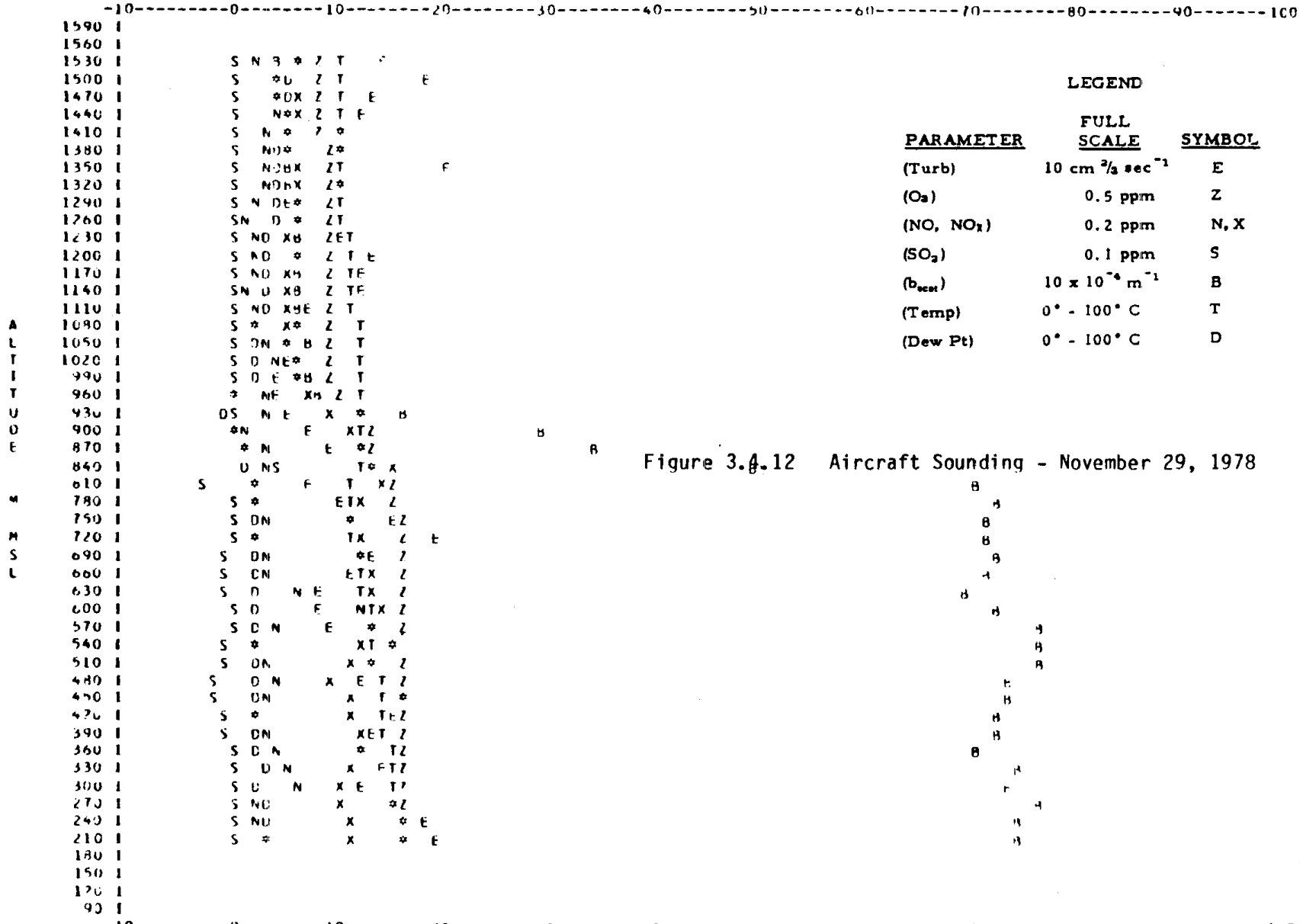


Figure 3.4.12 Aircraft Sounding - November 29, 1978

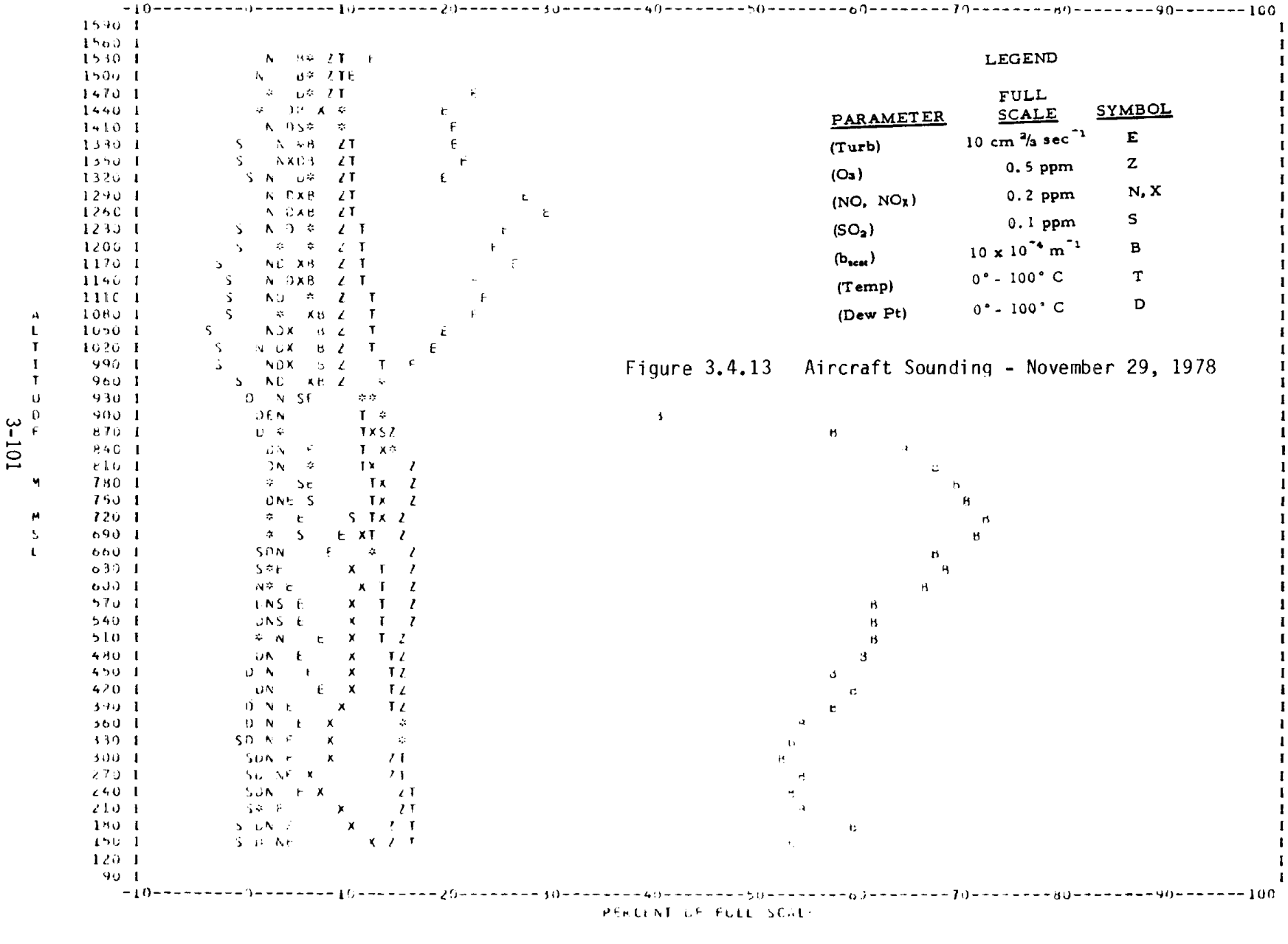


Figure 3.4.13 Aircraft Sounding - November 29, 1978

Aircraft Sampling - 30 November 1978

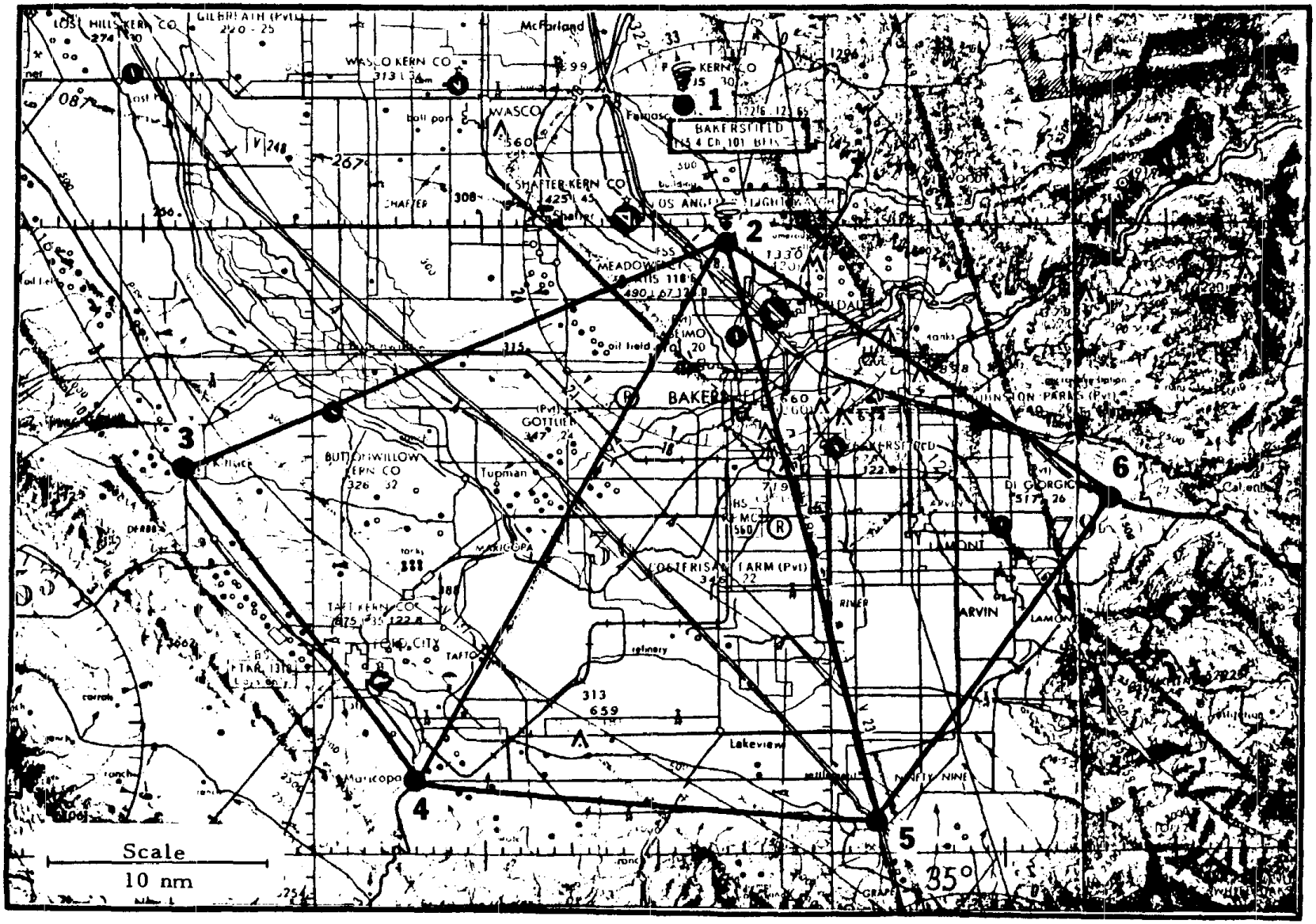
Aircraft sampling was conducted to (1) describe the regional air quality characteristics in the southern San Joaquin Valley and (2) to collect tracer samples for determination of the carryover from the previous days tracer release. The sampling pattern was designed to provide broad horizontal coverage within the surface mixing layer. Spirals were flown at two locations to the north of Bakersfield to document any temporal changes during sampling.

The flight pattern for November 30 is shown in Figure 3.4.14. A summary of pollutant concentrations observed on various segments of the pattern is given in Table 3.4.8. Detailed soundings to the north of Bakersfield are shown in Figures 3.4.15 to 3.4.17.

At 1330 PST the sounding near Bakersfield (Figure 3.4.15) shows a well-mixed layer about 860 m deep. High b_{scat} values were observed in the layer with low but significant values of O_3 and NO_x.

The sounding at 1500 PST on November 30 (Figure 3.4.16) shows a well-mixed layer from the surface to a depth of 900 m (above ground level). This layer was characterized primarily by large b_{scat} values. O_3, SO_2 and NO_x concentrations were low but well above background levels.

By 1640 PST (Figure 3.4.17) the mixed layer was about 800 m deep, still characterized primarily by high b_{scat} values and low NO_x (maximum 0.28 ppm) and low but significant O_3 levels (0.08 ppm). Mixing depth on November 30 was similar to November 29 but b_{scat} values were somewhat less on the 30th.



SAMPLING ROUTES 30 November 1978

Figure 3.4.14

Table 3.4.8

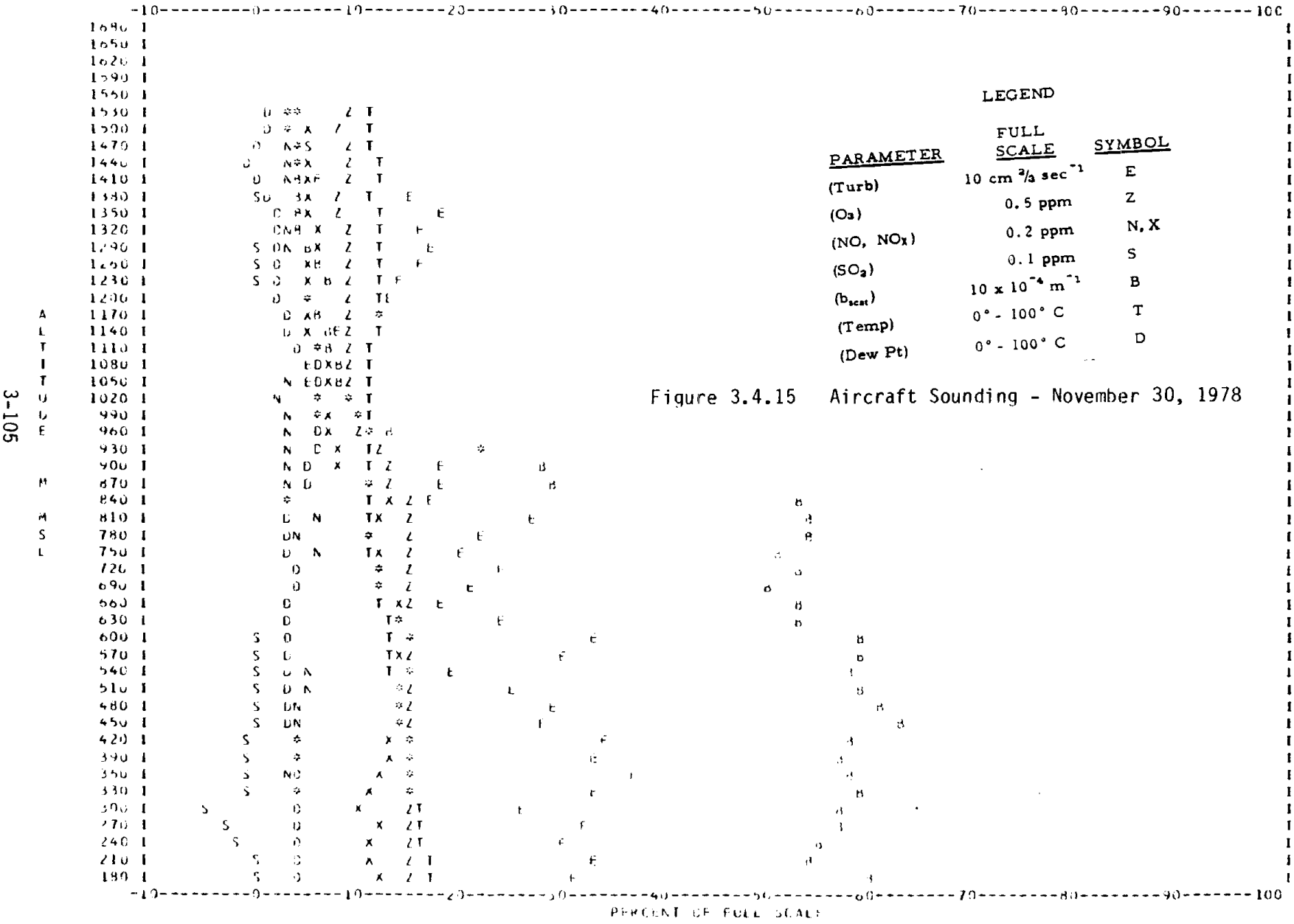
AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
NOVEMBER 30, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1330	1	60	79	310	700	0	14	18	32	-	-
1354	2-3	81	90	697	900	10	54	24	43	7	14
1415	3-4	76	92	629	970	20	45	32	47	8	15
1429	4-5	77	82	452	610	4	23	22	37	8	18
1446	5-6	77	83	523	740	1	7	22	30	15	23
1501	6-2	68	81	550	710	20	84	39	67	8	31
1521	2	57	76	299	690	4	9	18	30	7	24
1538	2-5	77	86	535	740	15	70	23	39	5	12
1601	5-4	76	83	469	590	6	9	23	30	4	11
1617	4-2	79	87	645	800	7	18	24	33	5	10
1640	1	56	75	299	670	5	7	14	28	4	11

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 11/30/78
CARTRIDGE/PASS: 1707 1
TIME: 13:30:51 TO 13:41:17

ROUTE: OVER POINT 1
MIN. GROUND ELEV.: 193 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.4.15 Aircraft Sounding - November 30, 1978

DATE: 11/30/78 ROUTE: 3V-2 POINT 2
CARTRIDGE/PASS: 1707 7
TIME: 15: 0:59 TO 15:10: 7 MIN. GROUND ELEV.: 152 M(MSL)

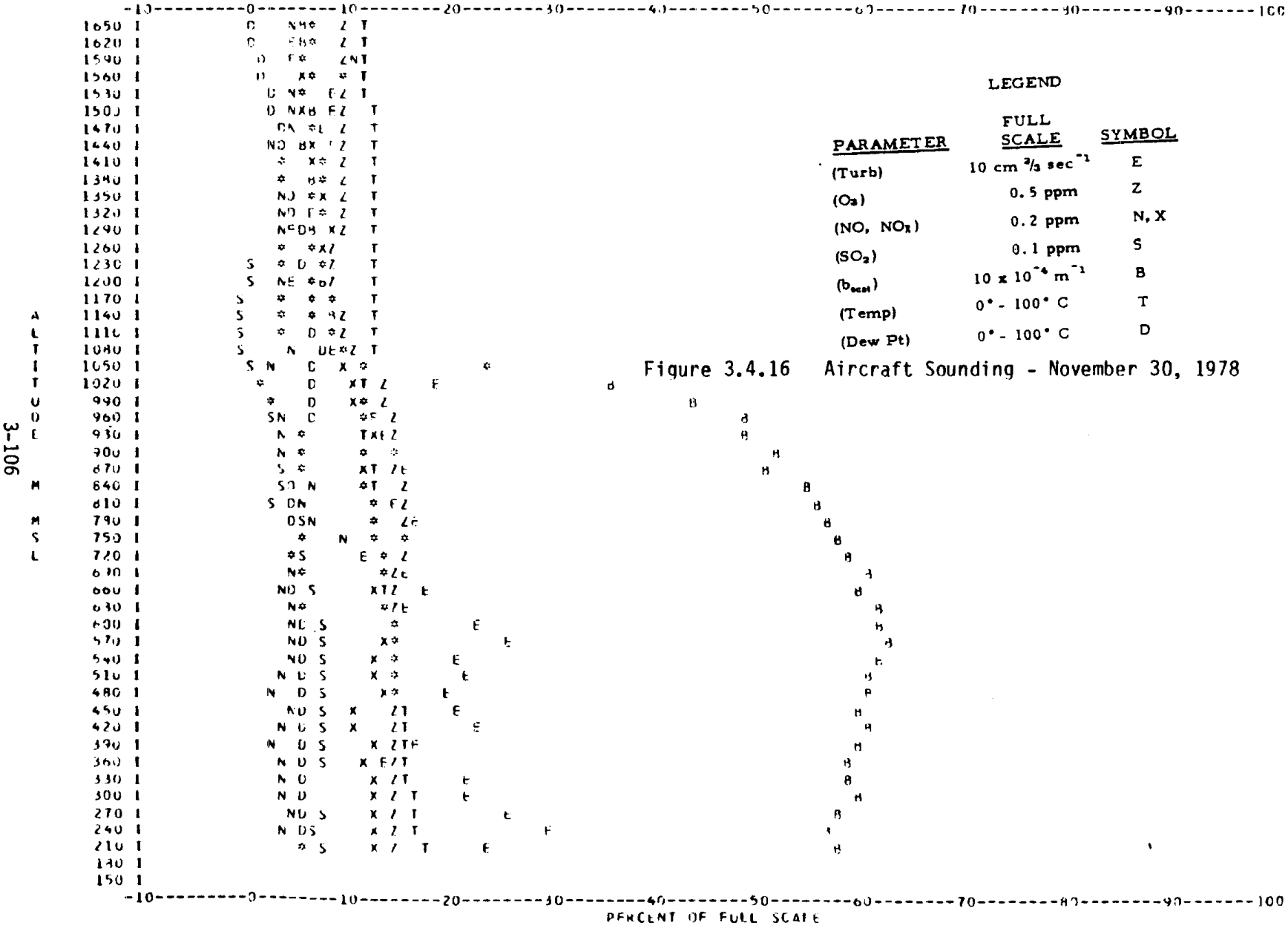
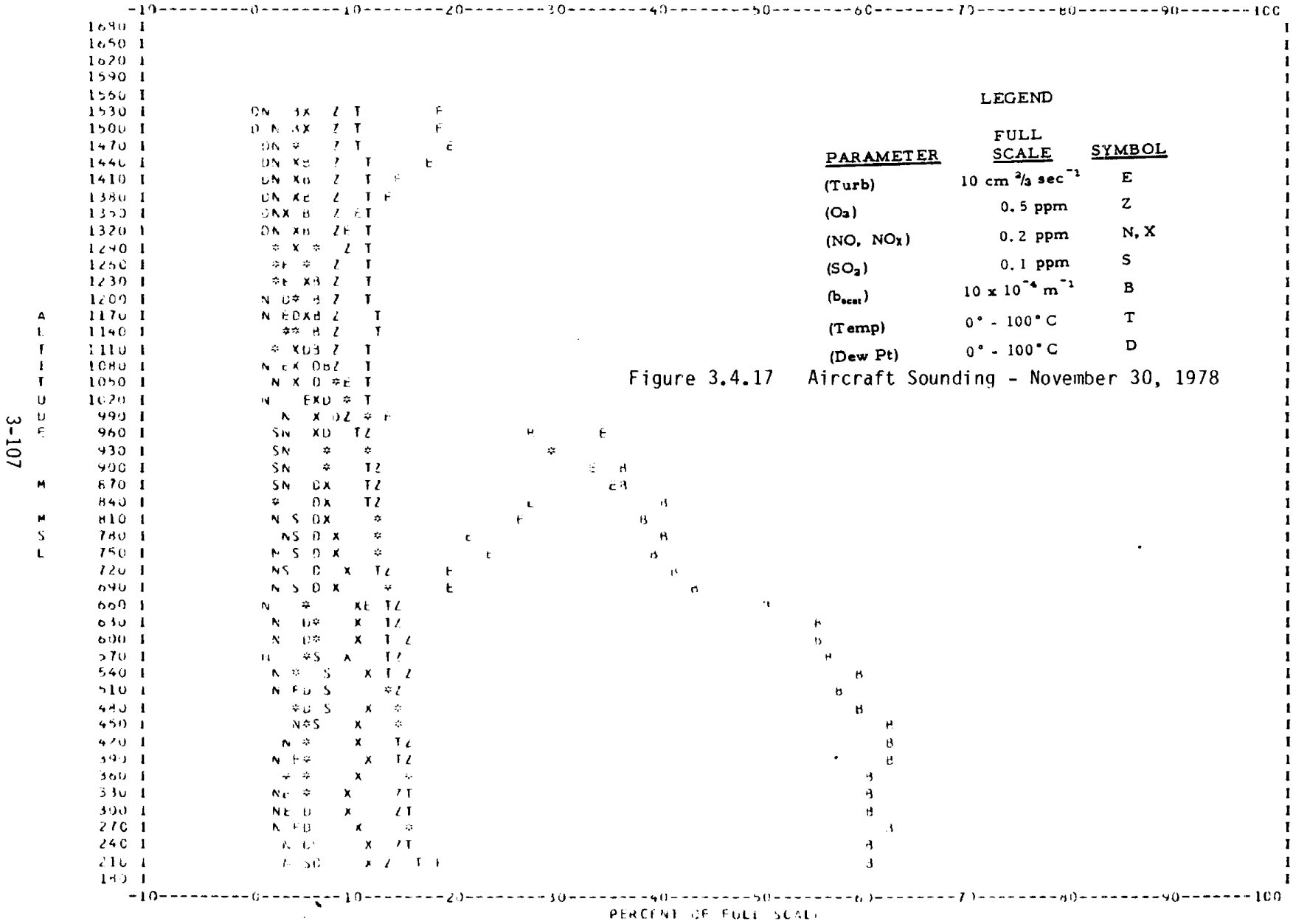


Figure 3.4.16 Aircraft Sounding - November 30, 1978

DATE: 11/30/78 ROUTE: OVER POINT 1
CARTRIDGE/PASS: 1707 11
TIME: 16:40:40 TO 16:49:19 MIN. GROUND ELEV.: 193 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.4.17 Aircraft Sounding - November 30, 1978

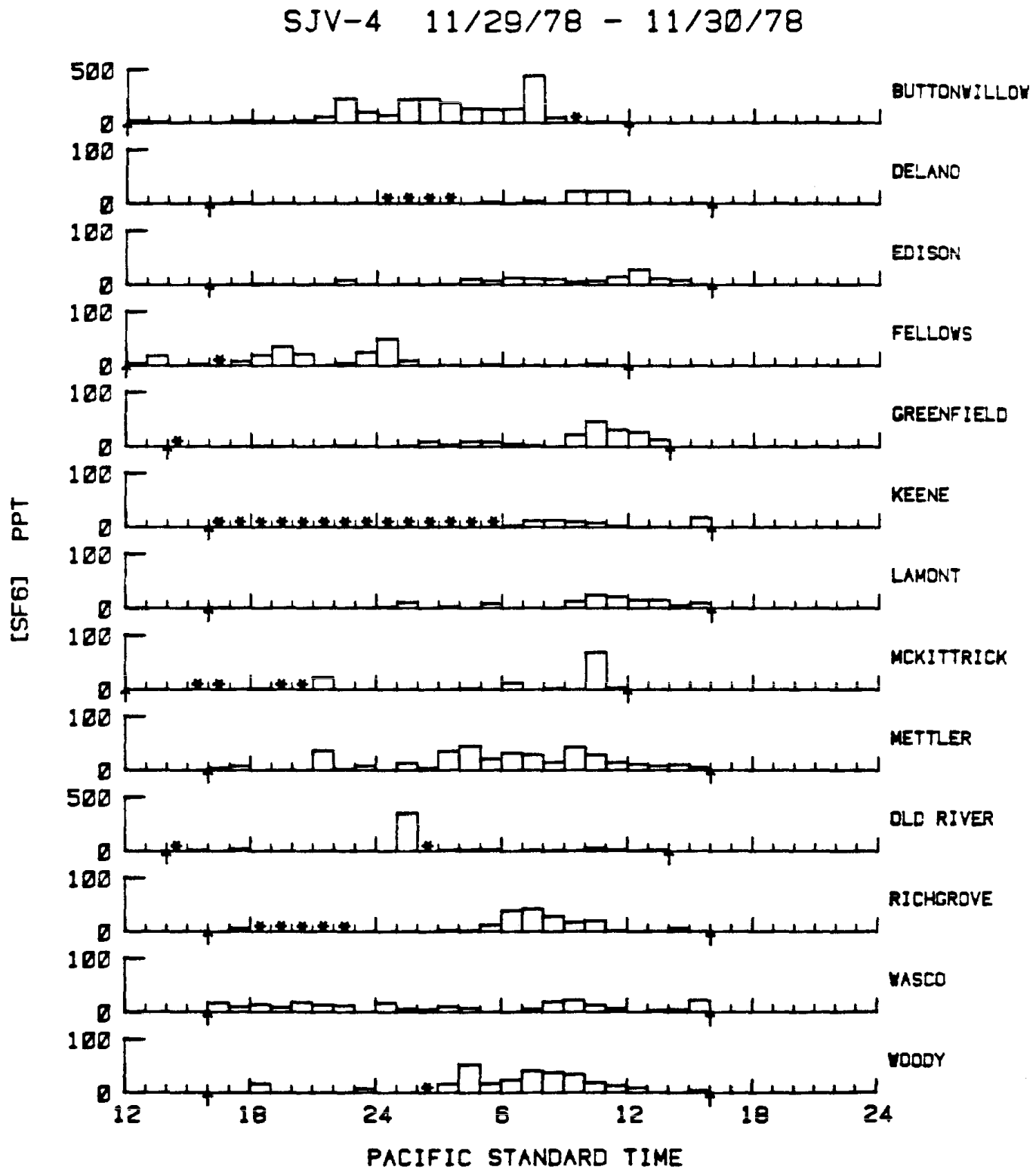
3.4.3 Tracer Test 4

Release Location: Valley Acres, Kern County
Time and Date: 1300-1700 PST, 11/29/78
Amount: 83 pounds of SF_6 per hour
Release conducted during essentially calm wind conditions

Initial transport west and north

Around 1630 PST, SF_6 was detected north and west of the release site during an airplane traverse. This was apparently the main body of the SF_6 plume in that concentrations as high as about 4500 ppt (7900 ppt/lb-mole SF_6 released/hr) were detected. The standard deviation in concentration within the plume was about 1.6 miles. The centerline of the tracer plume was about 5.5 miles west of the release site. Assuming that the tracer was transported on a straight line from the release site, the airplane traverse intersected the SF_6 plume at an angle of about 40 degrees. Thus the crosswind standard deviation in concentration of the tracer plume was about 1.6 sin (40 deg) = 1 mile. This corresponds to the crosswind dispersion of a Gaussian plume in unstable atmospheric conditions (Pasquill-Gifford stability class A or B). The crosswind dispersion of the tracer was probably enhanced due to the rough terrain in the vicinity of the release site.

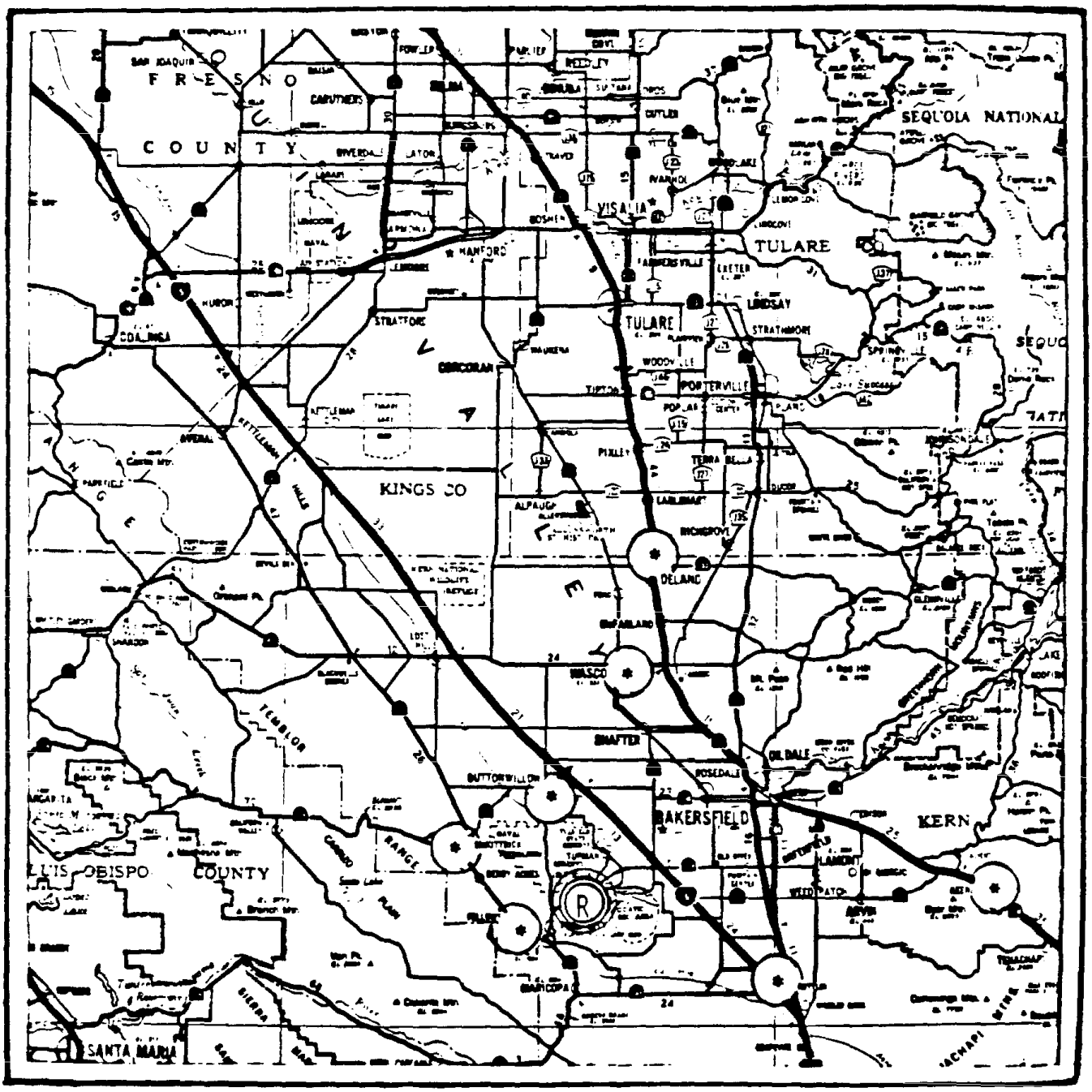
SF_6 was also detected at the Fellows hourly-averaged sampling site during the late afternoon. SF_6 concentration data at this and other fixed sampling sites are included in Figure 3.4.18 and the location of each site is shown in Figure 3.4.19. The first clear evidence of the arrival of SF_6 at Fellows was during the 1800-1900 PST sample. Since Fellows lies about 8 miles west-southwest of the release site, this suggests a net transport speed of at least 1.3 mph for the tracer. It should be remembered that due to the difficulties of measuring low wind speeds, surface wind measurements at the release site suggested a transport speed about an order of magnitude lower and in the opposite direction. Around 2000 PST, SF_6 concentrations of about 100 ppt were detected a few miles north of Fellows during an automobile traverse.



RELEASE: 416 LBS SF6 AT VALLEY ACRES
RELEASE TIME: 1200-1700 PST, 11/29/78

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.4.18



(*) INDICATES SAMPLER LOCATIONS

(R) IS THE RELEASE SITE

Figure 3.4.19

By late evening of the day of the release, the tracer began to be detected elsewhere in the valley. A small amount of tracer was detected at Buttonwillow about 1930 PST. This was verified by the detection of SF_6 concentrations as high as 490 ppt (860 ppt/lb-mole SF_6 released/hr) near Buttonwillow about 2000 PST. A shallow southerly flow was detected above the release site by pilot balloon measurements near the start of the release. The detection of SF_6 at Buttonwillow by 2000 PST suggests a net transport speed for this tracer plume of about 1.5-2 mph. An hourly-averaged sampler at Buttonwillow indicated that SF_6 was detected at Buttonwillow throughout the night. The average concentration detected between 2100 PST, 11/29/78 and 0900, 11/30/78 was 160 ppt (280 ppt/lb-mole SF_6 released/hr).

Transport during nighttime drainage winds

Near midnight, pilot balloon measurements at the release site showed westerly winds aloft. As would be expected, some of the SF_6 initially transported westward towards Fellows was returned to the area around the release site. During an automobile traverse conducted shortly after midnight (Traverse 1-5), SF_6 was detected along Highway 33 on the extreme western edge of the valley to near the junction of I-5 and Highway 119, in the center of the southern end of the valley. A maximum concentration of 377 ppt was detected a few miles east of the release site. An automobile traverse around 0500-0600 PST, 11/30/78 (Traverse 2-1), detected SF_6 in roughly the same locations as Traverse 1-5. During the later traverse, the maximum concentration detected was 73 ppt in the vicinity of the release site. Hourly-averaged SF_6 concentrations at Mettler, near the intersection of I-5 and Highway 99 in the southern central valley, were non-zero throughout the night. 350 ppt of SF_6 was detected at Old River, also near the center of the southern valley, between 0100 and 0200 PST.

Carryover of SF_6 initially transported westward

By mid-morning on the day following the release, the tracer was detected in most areas of the southern San Joaquin Valley. The maximum hourly-averaged SF_6 concentration detected at Mettler during the test was 43 ppt, detected between 0900 and 1000 PST, 11/30/78. 47 ppt was detected at Greenfield, southeast of Bakersfield, between 1000 and 1100 PST of the same day (the day following the

SF_6 release). At the same time, 24 ppt was detected at Lamont, also southeast of Bakersfield. As during the previous test, the tracer was transported across the centerline of the valley. If the maximum afternoon mixing height on this day (11/30/78) is assumed to be about 2000 ft, about 15-30 percent of the tracer originally released could be accounted for southeast of Bakersfield, on the east side of the nighttime convergence zone.

Carryover of SF_6 initially transported northward

The SF_6 originally transported into Buttonwillow was apparently also transported to the eastern side of the valley. An average of 28 ppt was detected at Woody, about 20 miles northeast of Bakersfield, between 0300 and 1200 PST, 11/30/78. At the neighboring town of Richgrove, an average of 26 ppt SF_6 was detected between 0500 and 1100 PST on the same morning. Lower concentrations (about 20 ppt) were detected at the Wasco and Delano sites, west of Richgrove and Woody, during the late morning. The tracer was dispersed by the afternoon winds and diluted by the growth of the mixing layer, but measurable SF_6 concentrations were detected throughout the afternoon of 11/30/78. The concentrations of SF_6 detected at these sites were approximately the same as those detected southeast of Bakersfield, suggesting that more than half of the SF_6 released could have remained within the valley at the start of the day following the release.

Transport eastward during the afternoon of second day

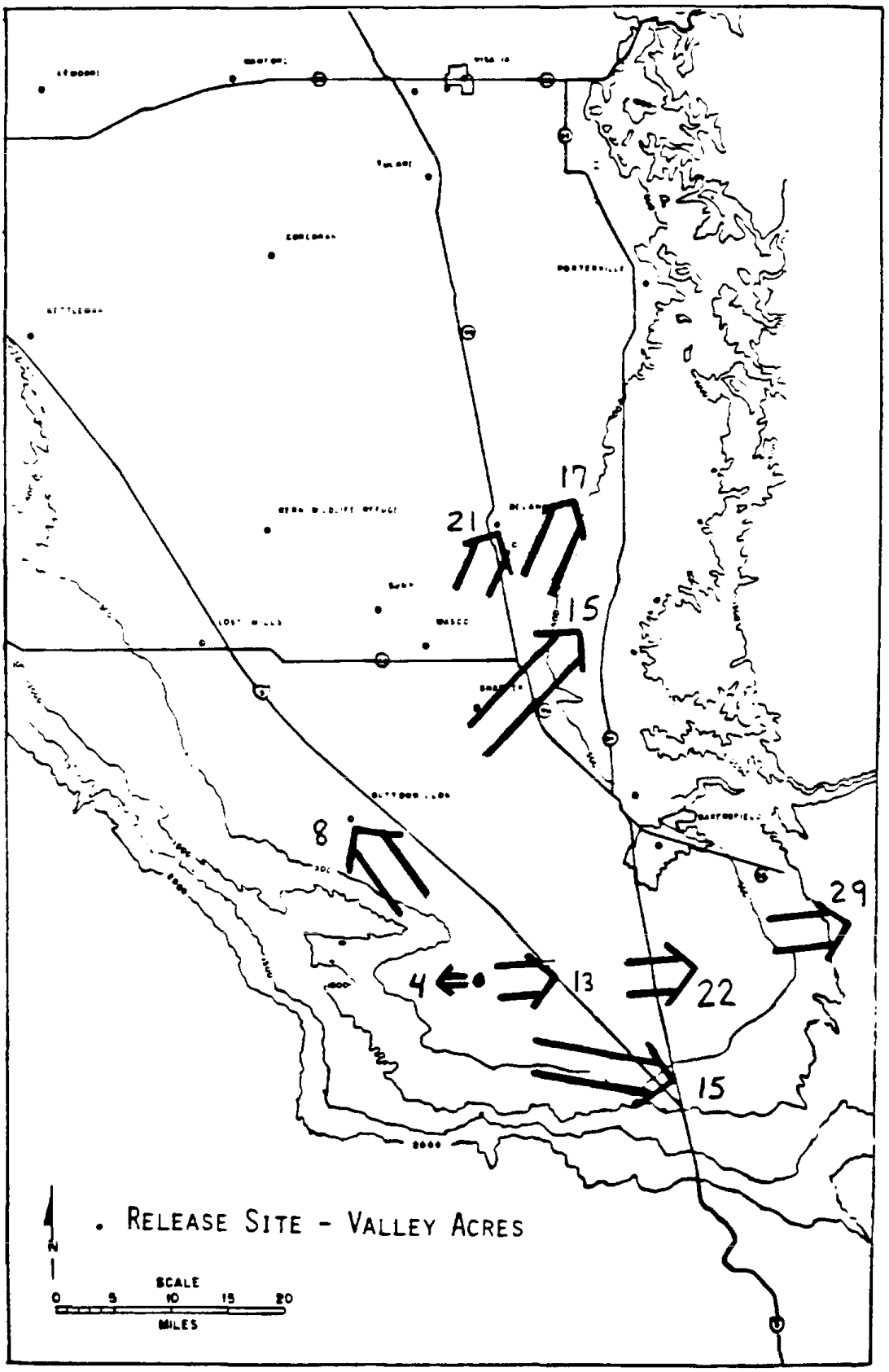
The tracer was transported eastward toward the Tehachapi Mountains and the Mojave Desert during the afternoon of the day following the release. During Traverse 1-7 conducted between 1352 and 1425 PST, an average of 12+/-2 ppt of SF_6 was detected as far east as Caliente in the Tehachapi Mountain foothills. During Traverse 1-9, conducted between 1726 and 1822 PST, only low levels of SF_6 could be detected west of Caliente (<=10 ppt), while east of Caliente, an average of 13+/-2 ppt was detected to the eastward extent of the traverse (Tehachapi). These traverses indicated that air located south and east of Bakersfield during the development of the afternoon westerly winds can apparently be transported out of the San Joaquin Valley and into the Mojave Desert. Test 3, however,

indicated that air located above Bakersfield or any point farther west may not be transported out of the valley before the nighttime wind reversal develops. Thus only a relatively small volume of air may be transported out of the valley due to this transport mechanism.

Summary

During this experiment, the SF_6 was released from Valley Acres, in the Elk Hills, under light and variable wind conditions. The tracer was transported at a net transport speed of between 1 and 2 mph to the north towards Buttonwillow and at the same or slightly lower speed to the west towards Fellows. Using airplane traverse data, it was possible to estimate that the initial tracer transport and dispersion could be modeled with the Gaussian plume model assuming unstable atmospheric conditions. Data limitations preclude a more detailed analysis of the initial transport and dispersion of the tracer. Figure 3.4.20 contains an overview of the tracer transport during the course of the test.

Westerly drainage winds (on the western side of the San Joaquin Valley) transported the tracer back towards the center of the valley. SF_6 was detected throughout the night at stations near the centerline of the southern valley. The generally eastward transport continued throughout the day following the release. The tracer originally transported northward towards Buttonwillow was detected along the foothills north of Bakersfield by hourly-averaged samplers at Richgrove and Woody. The SF_6 originally transported westward from the release site was detected first in the area southeast of Bakersfield, and by early evening, as far east as Tehachapi, which separates the San Joaquin Valley from the Mojave Desert. As during the previous test, the tracer was transported across the valley centerline. Clearly airborne pollutants released on either side of the valley can cross the valley center. As in previous tests there is evidence that a significant amount of SF_6 was carried over into the day following the release.



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (1200 PST, 11/29/78)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.4.20

3.5 Test 5 8-9 December 1978 - Lost Hills Release (1400-2030 PST)

3.5.1 Meteorology

General

Synoptic meteorological conditions during this test period were characterized by intense ridging aloft along the west coast as a deep low pressure system, which had for several days dominated west coast weather, moved eastward. As can be seen from Section 2, cold temperatures aloft persisted over central California on the 8th but a warming and stabilizing trend was being established and by the 10th temperatures at the 850 mb level were above the December mean. On the surface (Figure 3.5.1) a broad high pressure area centered in northern Nevada extended from the California coast east to the Rockies and from the Mexican to the Canadian borders. Weak pressure gradients and subsequent weak synoptic scale flow were again present in the region of interest. High broken clouds were present over the southern San Joaquin Valley and visibilities were excellent in some areas. Bakersfield reported 15-30 miles. Maximum surface temperature reported at Bakersfield was 55°F which is slightly below the mean for December.

Transport Winds

Surface winds at Lost Hills are shown in Table 3.5.1 for the 24-hour period starting from the beginning of the release. East to northeast winds prevailed during the early part of the release period. Beginning at 18 PST the drainage wind from the west commenced and continued through 07 PST. Thereafter, the characteristic northerly flow in the valley was observed.

Table 3.5.2 gives the 1000-foot winds at Lost Hills and Bakersfield for December 8-9. Winds at Lost Hills show an east to southeast direction until 10 PST on December 9th when the northerly flow began. It is apparent from these data that the westerly drainage wind at Lost Hills was quite shallow. Bakersfield also shows northeast to southeast winds through most of the night followed by northerly flow after mid-morning on the ninth.

FRIDAY, DECEMBER 8, 1978

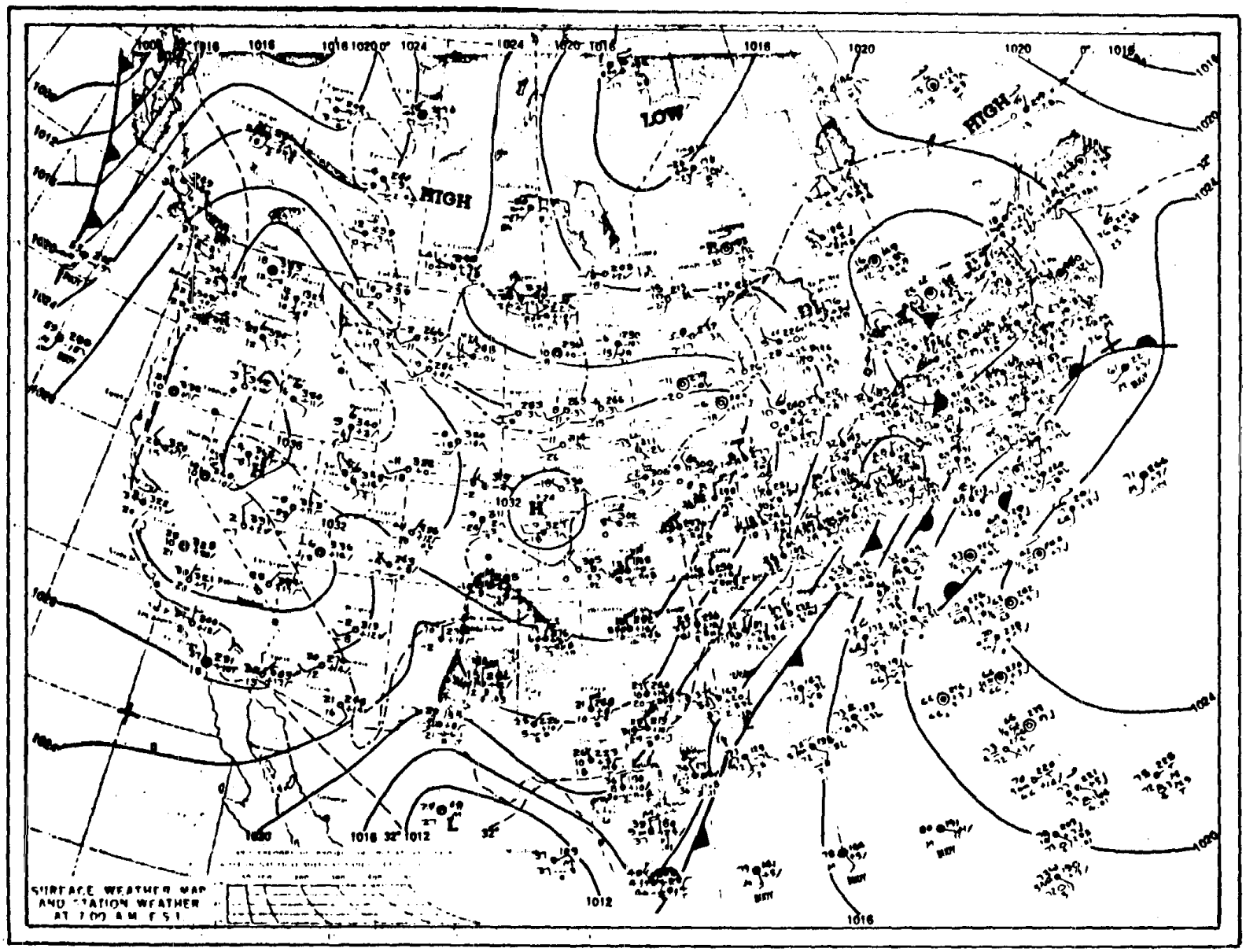


Figure 3.5.1 Surface Weather Map - December 8, 1978

Table 3.5.1

SURFACE WINDS AT LOST HILLS
DECEMBER 8-9, 1978

Time (PST)	Wind	Time (PST)	Wind
14	119°/2.4 m/s	02	263°/3.0 m/s
15	104 /1.9	03	275 /2.8
16	68 /1.4	04	268 /2.9
17	63 /1.5	05	270 /2.7
18	274 /1.0	06	276 /2.5
19	256 /3.0	07	264 /2.1
20	254 /3.2	08	308 /0.8
21	249 /3.1	09	51 /1.2
22	262 /3.4	10	51 /1.2
23	270 /2.6	11	7 /1.7
00	273 /2.5	12	360 /2.1
01	267 /2.8	13	8 /3.0

Table 3.5.2

1000-FOOT WINDS
DECEMBER 8-9, 1978

Date	Time (PST)	Lost Hills Wind	Bakersfield Wind
12-8	13	135°/2.3 m/s	25°/1.1 m/s
	14	119 /1.6	103 /2.8
	15	106 /3.3	47 /1.0
	16		
	17	115 /1.5	352 /2.3
	19	63 /2.3	53 /4.4
	20	78 /2.4	
	22	116 /2.5	
12-9	01	74 /2.5	
	05		140 /2.1
	07	141 /0.4	152 /1.2
	09	151 /0.3	154 /1.7
	10	15 /0.7	
	11	348 /1.6	46 /1.1
	13		321 /1.9

These wind patterns are shown on a regional basis in Figures 3.5.2 to 3.5.4. Winds at 16 PST on the west side of the valley were primarily from the east. The typical flow during the night (Figure 3.5.3) indicates westerly winds on the west side of the valley and the reverse on the east side. A convergence line is suggested in the middle of the valley. By 13 PST on December 9 (Figure 3.5.4) the winds were northerly throughout the southern part of the valley.

Mixing Heights

Mixing heights as determined from aircraft soundings on December 8 and 9 are given in Table 3.5.3. Depths of the mixing layers were generally about 700 m (above ground level) on both days.

Table 3.5.3

AIRCRAFT MIXING HEIGHTS

Time (PST)	Location*	Mixing Height (agl) (m)
	December 8, 1978	
1352	9 NW BFL AP	710
1429	52 WNW BFL AP	950
1600	52 WNW BFL AP	740
1646	9 NW BFL AP	740
	December 9, 1978	
1301	9 NW BFL AP	620
1515	9 NW BFL AP	710

*(distances in miles)

3.5.2 Air Quality

Surface Air quality

Maximum ozone concentrations throughout the valley on December 8 was 0.05 ppm at McKittrick and Union Island. The remainder of the valley experienced ozone concentrations of 0.04 ppm or less. A regional map of maximum ozone concentrations on December 8 is shown in Figure 3.5.5. Maximum pollutant concentrations of other parameters in the valley on December 8 are shown in Table 3.5.4.

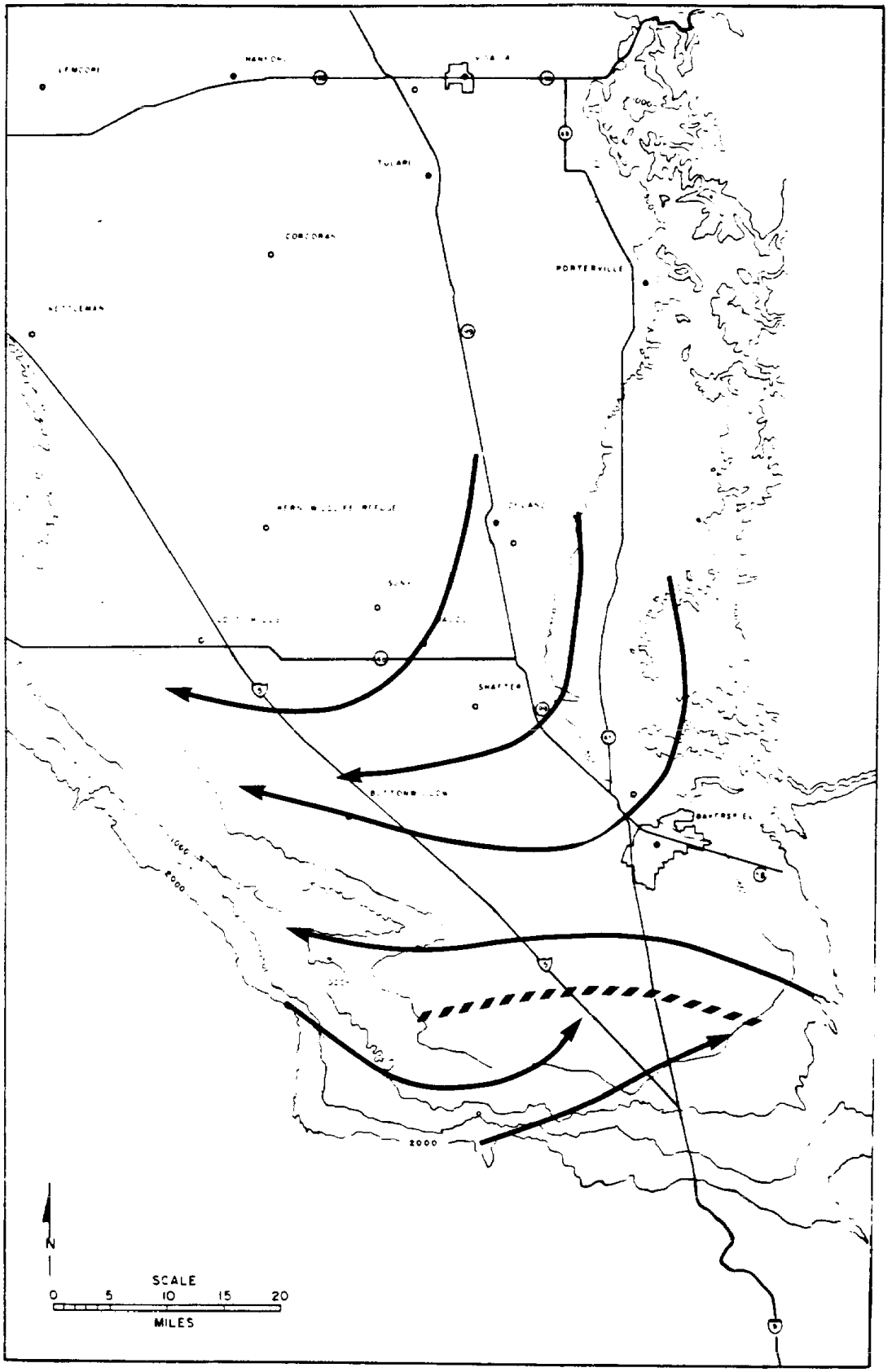


Figure 3.5.2 Surface Streamlines - 8 December 1978 (16 PST)

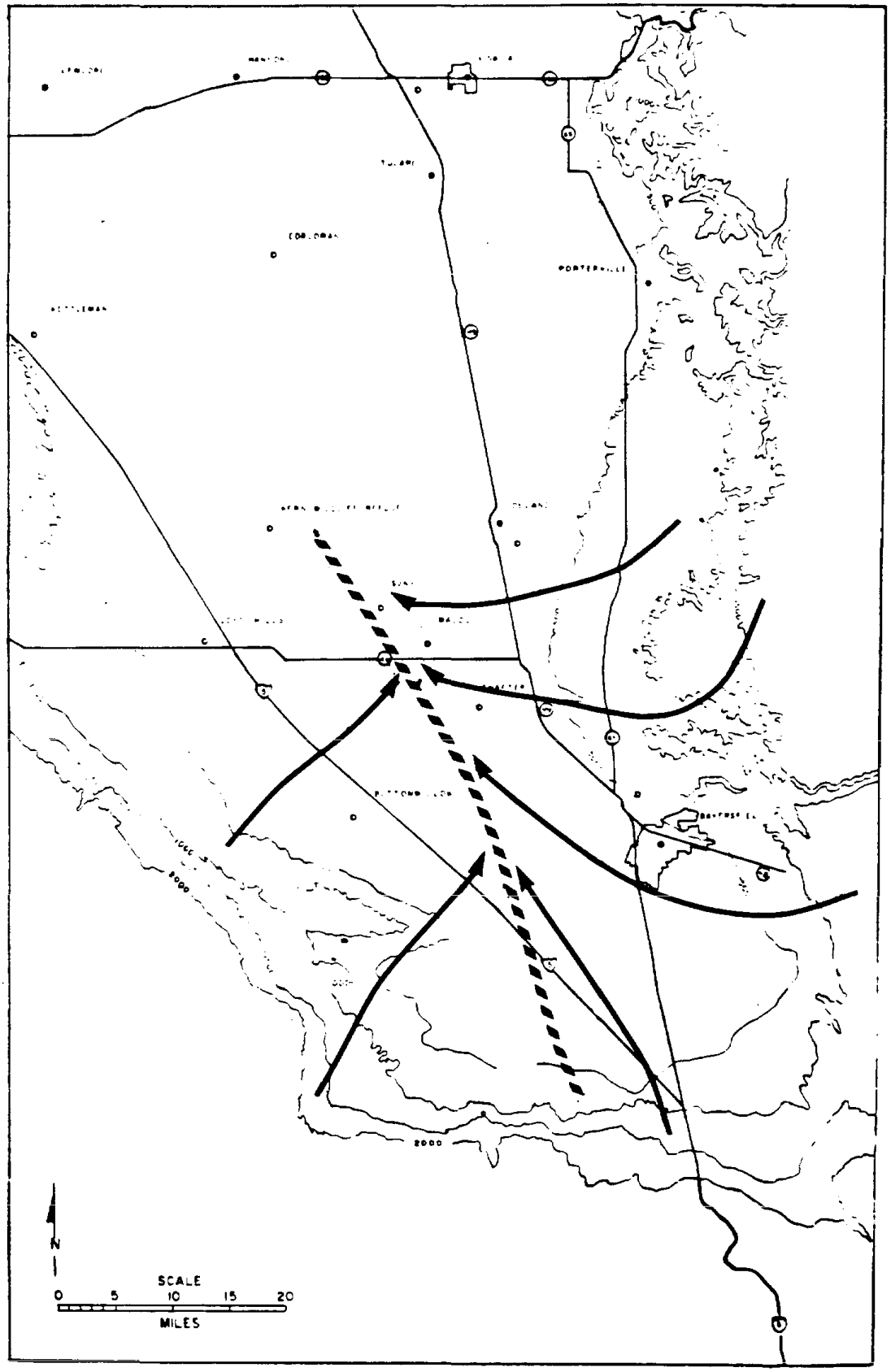


Figure 3.5.3 Surface Streamlines - 9 December 1978 (01 PST)

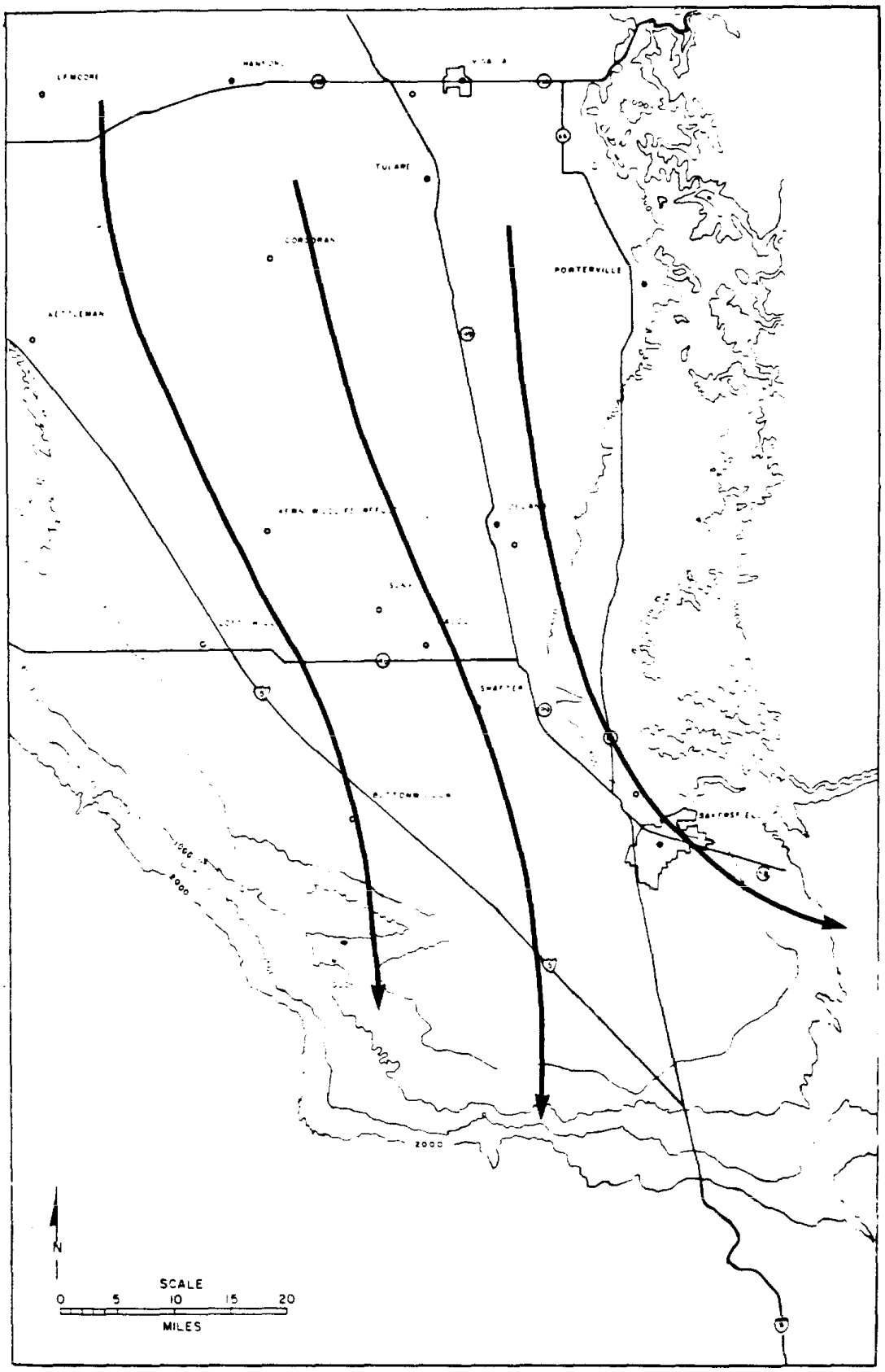


Figure 3.5.4 Surface Streamlines - 9 December 1978 (13 PST)

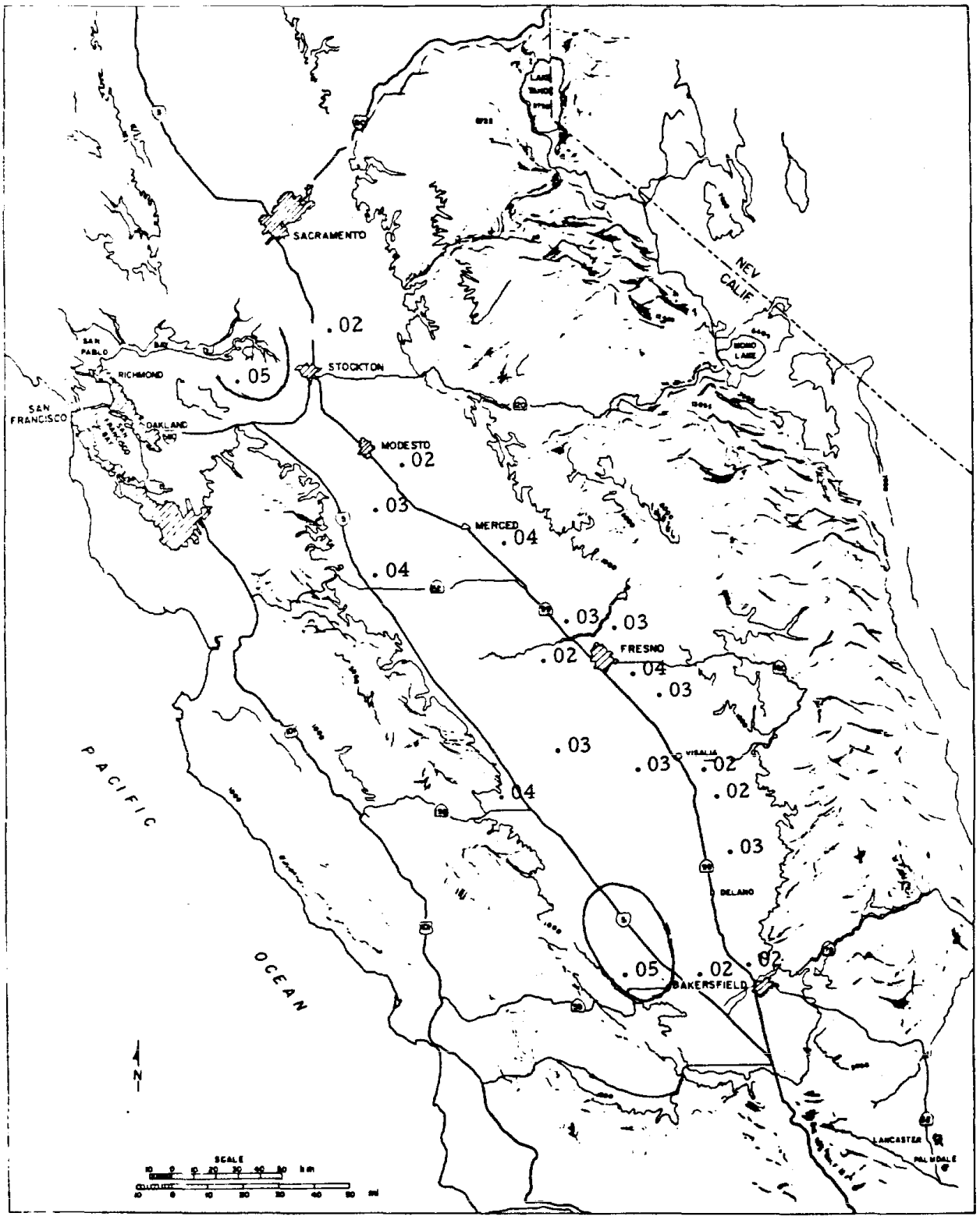


Figure 3.5.5 Maximum Hourly Ozone Concentrations (ppm) - December 8, 1978

Table 3.5.4

MAXIMUM POLLUTANT CONCENTRATIONS
DECEMBER 8, 1978

Location	CO (ppm)	SO_2 (ppm)	NO_x (ppm)
Fresno-Olive	18		
Oildale		0.08	
Fresno-Olive			1.09
Reedley	2.4	0.08	1.93
Radome		0.03	0.62
Lost Hills		0.02	0.36

A summary of 1300 PST visibilities at a number of airports in the valley on December 8 is given in Table 3.5.5. No visibilities less than five miles were observed. In addition, considerable variation in visibility was noted, in contrast with the rather uniform values reported in other test periods. This pronounced variation in visibility within the region is associated with stabilizing conditions in which a capping, thermal lid had not yet become well-established in the valley.

Table 3.5.5

1300 PST VISIBILITIES

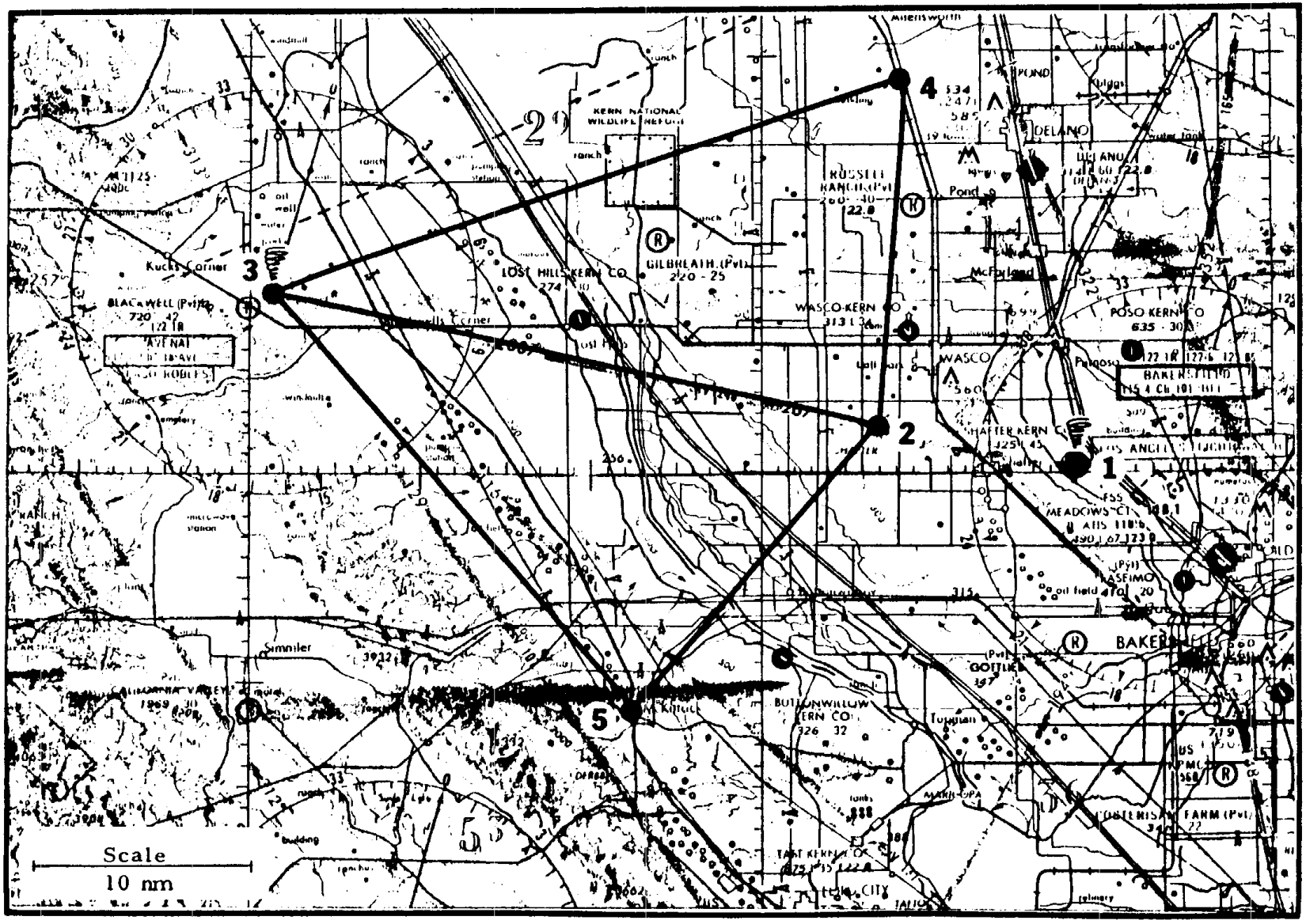
Station	Visibility (miles)
Sacramento	15
Stockton	7
Modesto	5 HK
Crow's Landing	6 H
Merced	5 H
Fresno	10
Lemoore NAS	7
Visalia	7
Bakersfield	30

Aircraft Sampling 8 December 1978

In conjunction with a tracer release from Lost Hills; the aircraft sampled in the southern San Joaquin Valley from about 10 miles north of Lost Hills to McKittrick in the south. The flight pattern was designed to surround the release region and to sample the west side oil fields. Spirals were flown on the east side and the west side of the valley at the start and end of sampling to provide information on atmospheric stability and distribution of pollutants in the vertical.

As a result of a earlier period of frontal passages in the area and subsequent reduced atmospheric stability, relatively good air quality and visibility prevailed. Ground source plumes were observed moving to the west during the flight. Except in the vicinity of source regions, b_{scat} and concentrations of gaseous pollutants were horizontally uniform. Ozone concentrations were generally in the 30-40 ppb range in response to cool ambient temperatures. At the start of sampling, surface mixing was observed to 2650 ft msl on the east side of the valley and to 3750 ft msl on the west side. By the end of sampling (~1600 PST) the atmosphere had stabilized enough such that only weak mixing was evident at both locations. Although several SO_2 and NO_x plumes were encountered along the west edge of the valley in ths South Belridge Oil Field area, concentrations were light. Maximum concentrations of SO_2 (27 ppb) were found in an elevated plume between 2500 and 4000 ft msl over the Bakersfield VOR on the late afternoon (1647 PST) spiral. A double haze layer was visually observed on the last east-west traverse (Pass 10). The maximum concentrations of NO_x (84 ppb) were observed near the McKittrick area.

Figure 3.5.6 shows the sampling flight pattern on December 8. Table 3.5.6 summarizes the pollutant concentrations observed on various portions of the flight pattern. Detailed soundings northwest of Bakersfield and to the west of Lost Hills are shown in Figures 3.5.7 to 3.5.10.



SAMPLING ROUTES 8 December 1978

Figure 3.5.6

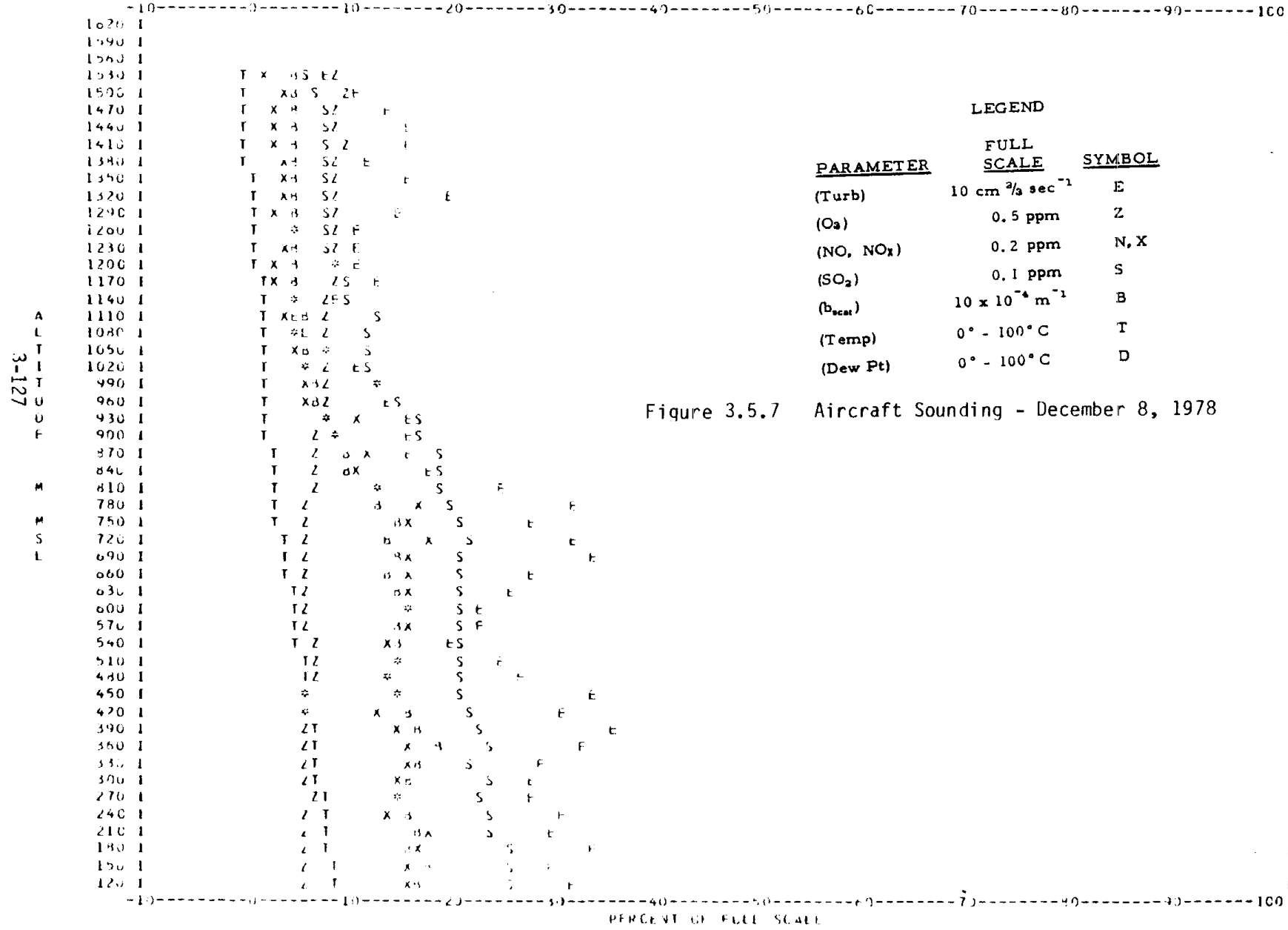
Table 3.5.6

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
DECEMBER 8, 1978

		O_3		b_{scat}		SO_2*		NO_x		NO	
Start Time (PST)	Location (Point)	Mean (ppb)	Max (ppb)	Mean ($x10^{-6}m^{-1}$)	Max	Mean (ppb)	Max (ppb)	Mean (ppb)	Max (ppb)	Mean (ppb)	Max (ppb)
1352	1	33	45	92	230	15	25	17	49	-	-
1412	2-3	34	38	114	200	1	5	11	38	-	-
1429	3	38	43	86	150	0	2	9	22	-	-
1451	3-4	33	43	145	250	2	5	14	34	-	-
1512	4-2	31	36	159	230	5	7	18	38	-	-
1530	2-5	30	34	135	200	6	11	16	84	-	-
1542	5-3	31	35	121	200	4	16	15	33	-	-
1600	3	38	48	95	170	1	7	9	26	-	-
1620	3-2	32	35	126	210	4	11	11	28	-	-
1646	1	32	49	110	300	9	27	13	41	-	-

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 12/ 8/78 ROUTE: OVER POINT 1
CARTRIDGE/PASS: 1717 1
TIME: 13:52: 9 TO 14: 1:33 MIN. GROUND ELEV.: 129 M(MSL)

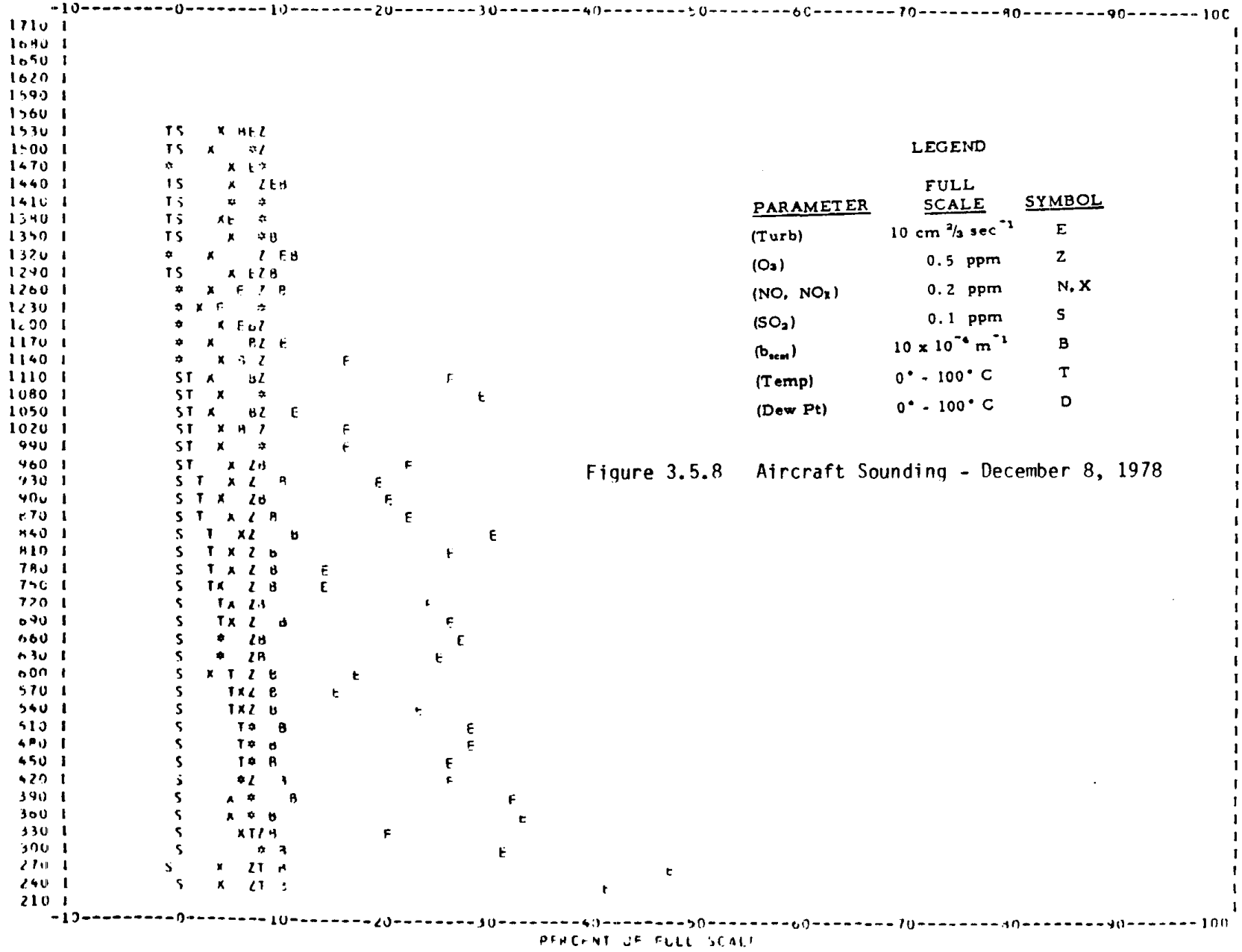


LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.5.7 Aircraft Sounding - December 8, 1978

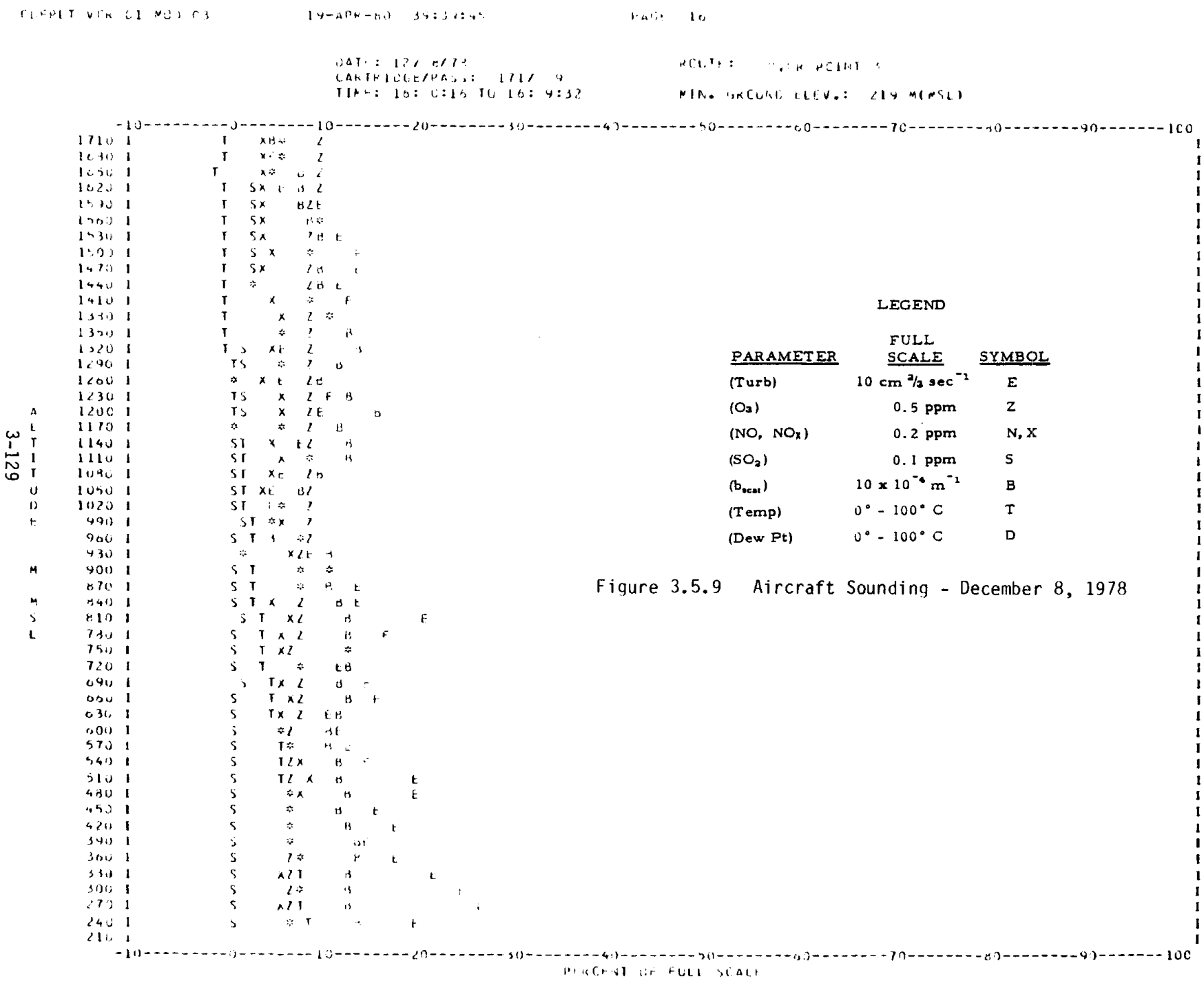
DATE: 12/ 8/78 ROUT : OVER POINT 1
CARTRIDGE/PASS: 1717 3
TIME: 14:29:59 TO 14:38:33 MIN. GROUND ELEV.: 219 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.5.8 Aircraft Sounding - December 8, 1978



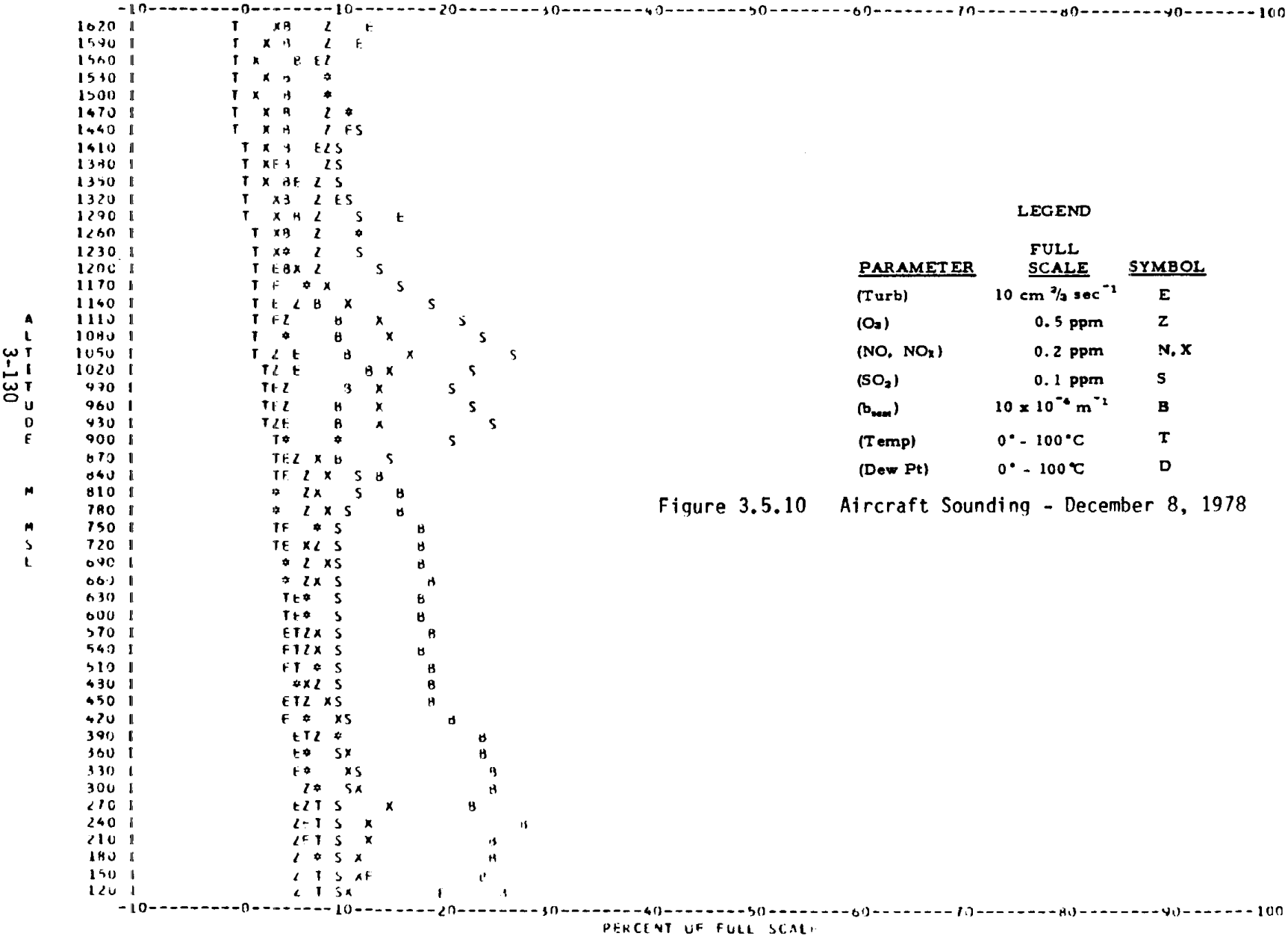
LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.5.9 Aircraft Sounding - December 8, 1978

DATE: 12/ 8/78
CARTRIDGE/PASS: 171/ 11
TIME: 16:46: 1 TO 16:57: 4

ROUTE: OVER POINT 1
MIN. GROUND ELEV.: 129 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100°C	T
(Dew Pt)	0° - 100°C	D

Figure 3.5.10 Aircraft Sounding - December 8, 1978

The first sounding at 1352 PST (Figure 3.5.7) shows multiple, mixed layers with tops of about 320 m and 710 m. b_{scat} values were relatively low in these layers but both SO_2 and NO_x concentrations were significantly above ground levels.

The 1424 PST sounding (Figure 3.5.8) was made on the west side of the valley to the west of Lost Hills. The mixing depth was near 700 m (above ground level) as indicated by the turbulence measurements. Pollutant parameters, including b_{scat}, were extremely low and generally of insufficient magnitude to aid in defining a mixing layer.

The 1600 PST sounding (Figure 3.5.9) shows a mixed layer about 740 m at the same location as the previous sounding. b_{scat} values had increased sufficiently to use in identifying the top of the mixed layer but were still very low. All other pollutant concentrations were near background levels.

The 1646 PST sounding (Figure 3.5.10) was taken at the same location as Figure 3.5.7. In the three-hour period between soundings, the b_{scat} values had increased significantly in the low levels while the SO_2 concentrations in the mixed layer had decreased markedly. Mixing depth at 1646 PST was slightly lower than the earlier sounding. A marked SO_2 plume aloft was evident in the sounding between 800 and 1050 m above ground level.

Aircraft Sampling - 9 December 1978

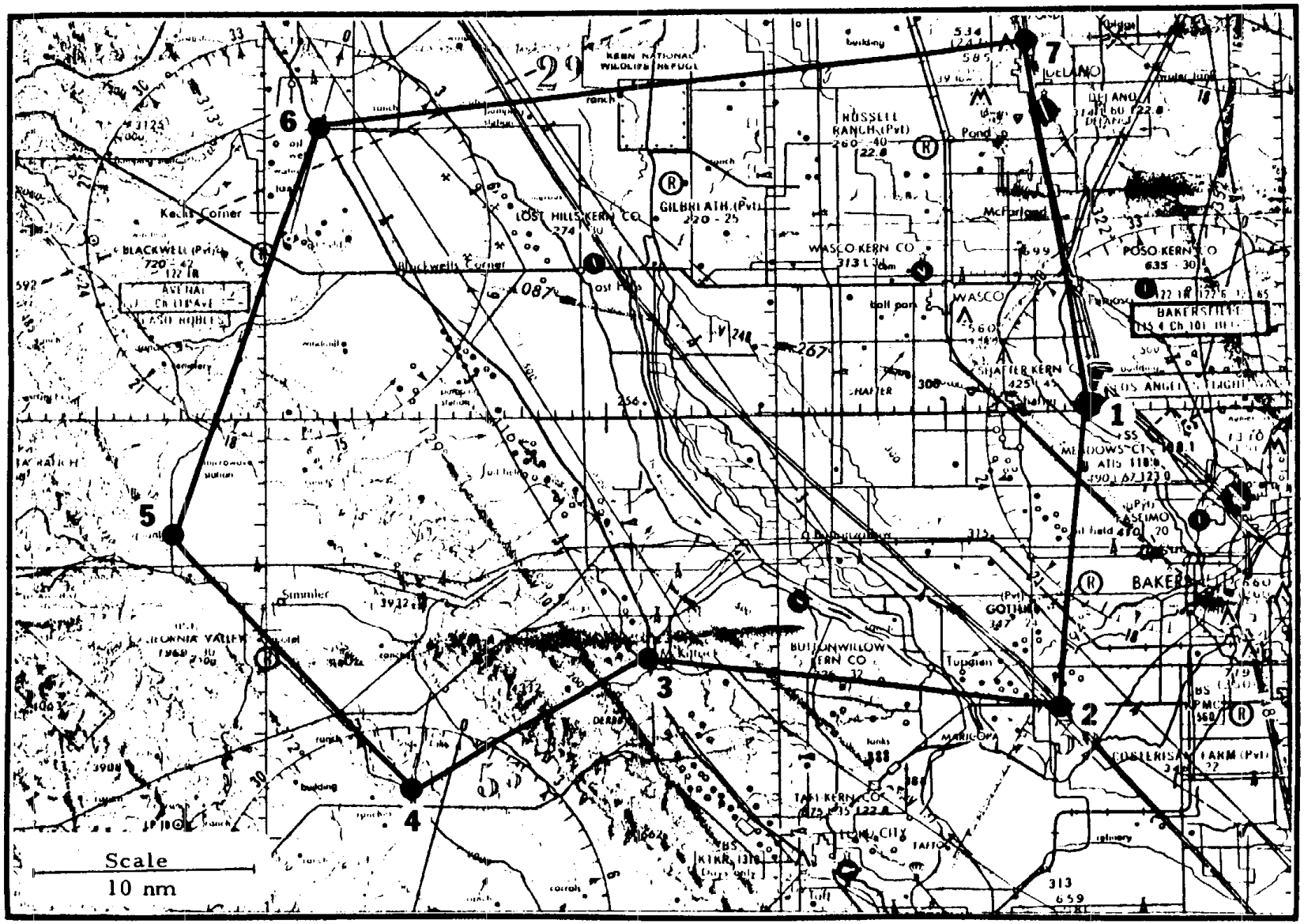
This sampling flight was designed primarily to define the tracer material carry-over and distribution from the previous days tracer release. To this end, the flight pattern consisted of a series of traverses within the surface mixing layer which formed a box roughly enclosing the area from Delano on the north to the southern extreme of the valley, west to the California Valley, and north to above Lost Hills. Spirals were flown over the Shafter airport at the beginning and end of sampling to define conditions in the vertical.

The surface mixing extended to 2100 ft msl at the start of sampling and deepened to 2600 ft msl by the end of sampling. The accumulation of pollutants within the valley under stagnating conditions was becoming evident from the increase in b_{scat} from the previous days sampling. Except in the

vicinity of local sources, the horizontal distribution of air quality parameters was uniform in the Central Valley. In the California Valley, levels of NO_x and b_{scat} were lower (10 ppb and 200 x 100^{-6} m^{-1}, respectively) but uniform. Only low concentrations of SO_2 and NO_x were observed throughout sampling. High b_{scat} readings resulting from agricultural burning were encountered in the vicinity of Delano.

The flight pattern on December 9 is shown in Figure 3.5.11. A summary of pollutant concentrations observed during the flight is given in Table 3.5.7. Detailed soundings made during the flight near Bakersfield are shown in Figures 3.5.12 and 3.5.13.

Mixing depths on December 9 were substantially lower than observed on December 8, reflecting the stabilizing influence of increasing temperatures aloft. b_{scat} values were similar in both soundings and were considerably higher than on December 8, again indicating the rapid build up in particulate loading during a stabilizing period. NO_x concentrations were significantly above background levels but SO_2 values were quite low in both soundings.



SAMPLING ROUTES 9 December 1978

Figure 3.5.11

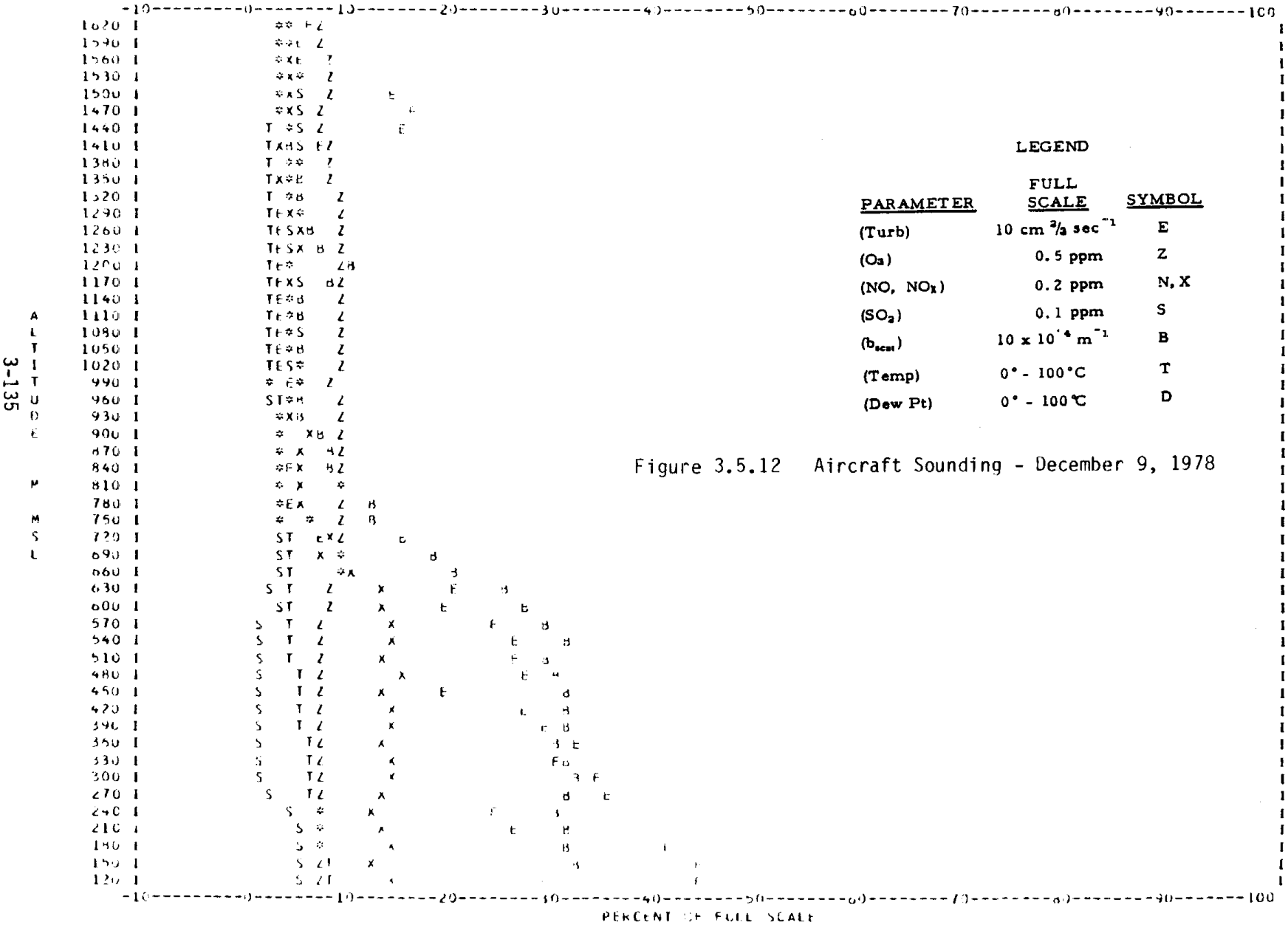
Table 3.5.7

AIR QUALITY MEASUREMENTS CARB SAN JOAQUIN VALLEY PROJECT
DECEMBER 9, 1978

Start Time (PST)	Location (Point)	O_3 Mean (ppb)	O_3 Max (ppb)	b_{scat} Mean ($x10^{-6}m^{-1}$)	b_{scat} Max ($x10^{-6}m^{-1}$)	SO_2* Mean (ppb)	SO_2* Max (ppb)	NO_x Mean (ppb)	NO_x Max (ppb)	NO Mean (ppb)	NO Max (ppb)
1301	1	40	49	127	370	3	11	14	32	-	-
1329	1-2	34	40	303	390	1	9	26	34	-	-
1340	2-1	34	41	283	390	0	12	23	45	-	-
1356	3-4	37	44	100	310	0	0	14	37	-	-
1408	4-5	37	42	128	230	1	4	14	21	-	-
1422	5-6	39	43	218	300	0	2	14	21	-	-
1441	6-7	38	44	320	840	3	27	20	36	-	-
1504	7-1	32	36	305	430	2	5	24	36	-	-
1527	1	38	48	134	370	1	3	13	31	-	-

* SO_2 instrument subject to long term baseline drift resulting in a possible background error as great as 20 ppb.

DATE: 127 9/78 ROUTE: OVER POINT 1
CARTRIDGE/PASS: 1727 1
TIME: 13: 1:45 TO 13:13:24 MIN. GROUND ELEV.: 129 M(MSL)



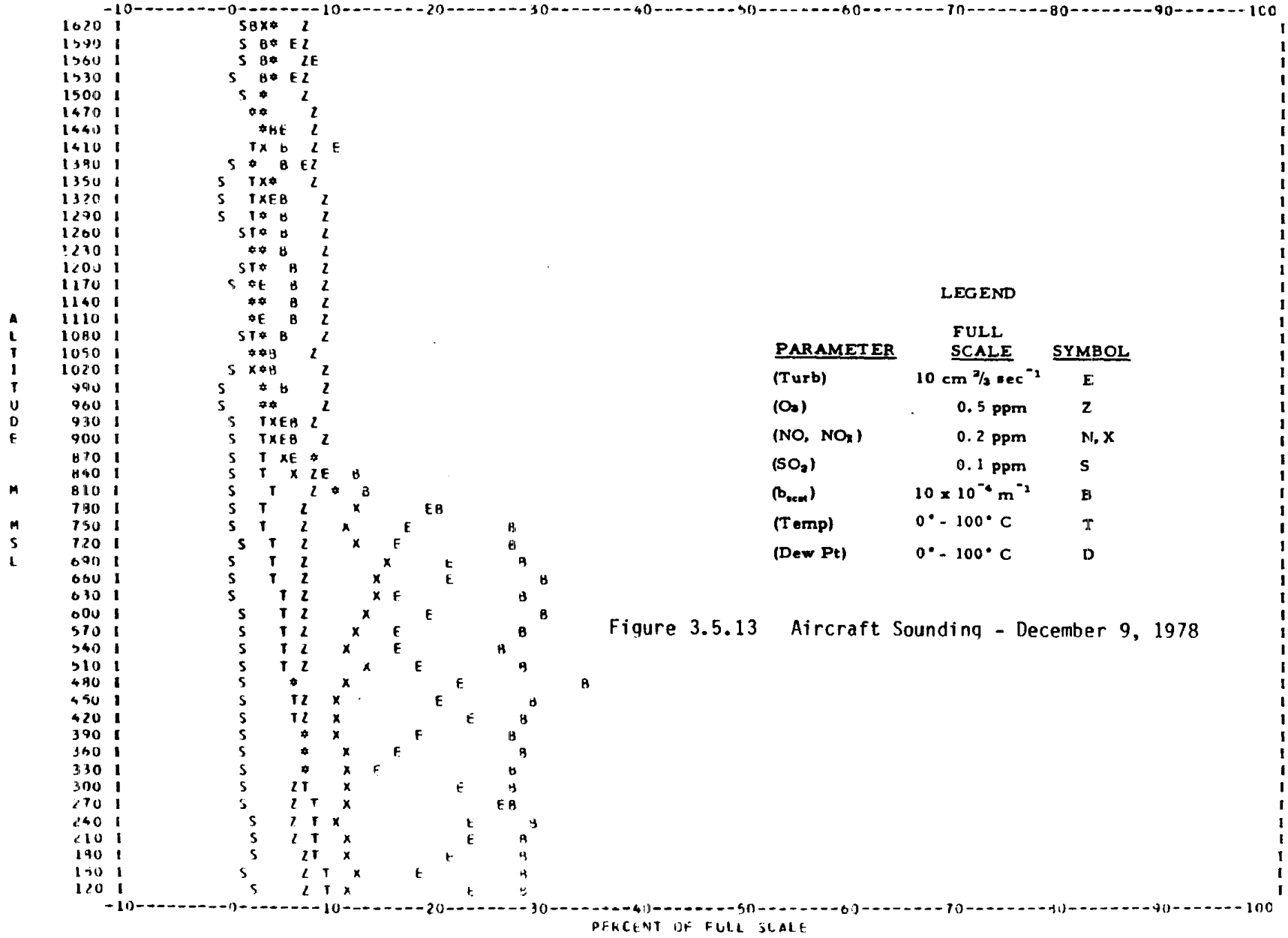
LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100°C	T
(Dew Pt)	0° - 100°C	D

Figure 3.5.12 Aircraft Sounding - December 9, 1978

DATE: 12/ 9/78
CARTRIDGE/PASS: 1727 9
TIME: 15:15:40 TO 15:27: 1

ROUTE: OVER POINT 1
MIN. GROUND ELEV.: 129 M(MSL)



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(Turb)	10 cm $^{2/3}$ sec^{-1}	E
(O_3)	0.5 ppm	Z
(NO, NO_x)	0.2 ppm	N, X
(SO_2)	0.1 ppm	S
(b_{scat})	10 x 10^{-4} m^{-1}	B
(Temp)	0° - 100° C	T
(Dew Pt)	0° - 100° C	D

Figure 3.5.13 Aircraft Sounding - December 9, 1978

3.5.3 Tracer Test 5

Release Location: Lost Hills, Kern County
Time and Date: 1400-2030 PST, 12/8/78
Amount: 97 pounds of SF_6 per hour
Release conducted during southeasterly winds aloft. Shallow surface layer winds shifted from southerly through northeasterly to westerly during the course of the release.

Initial transport northwest

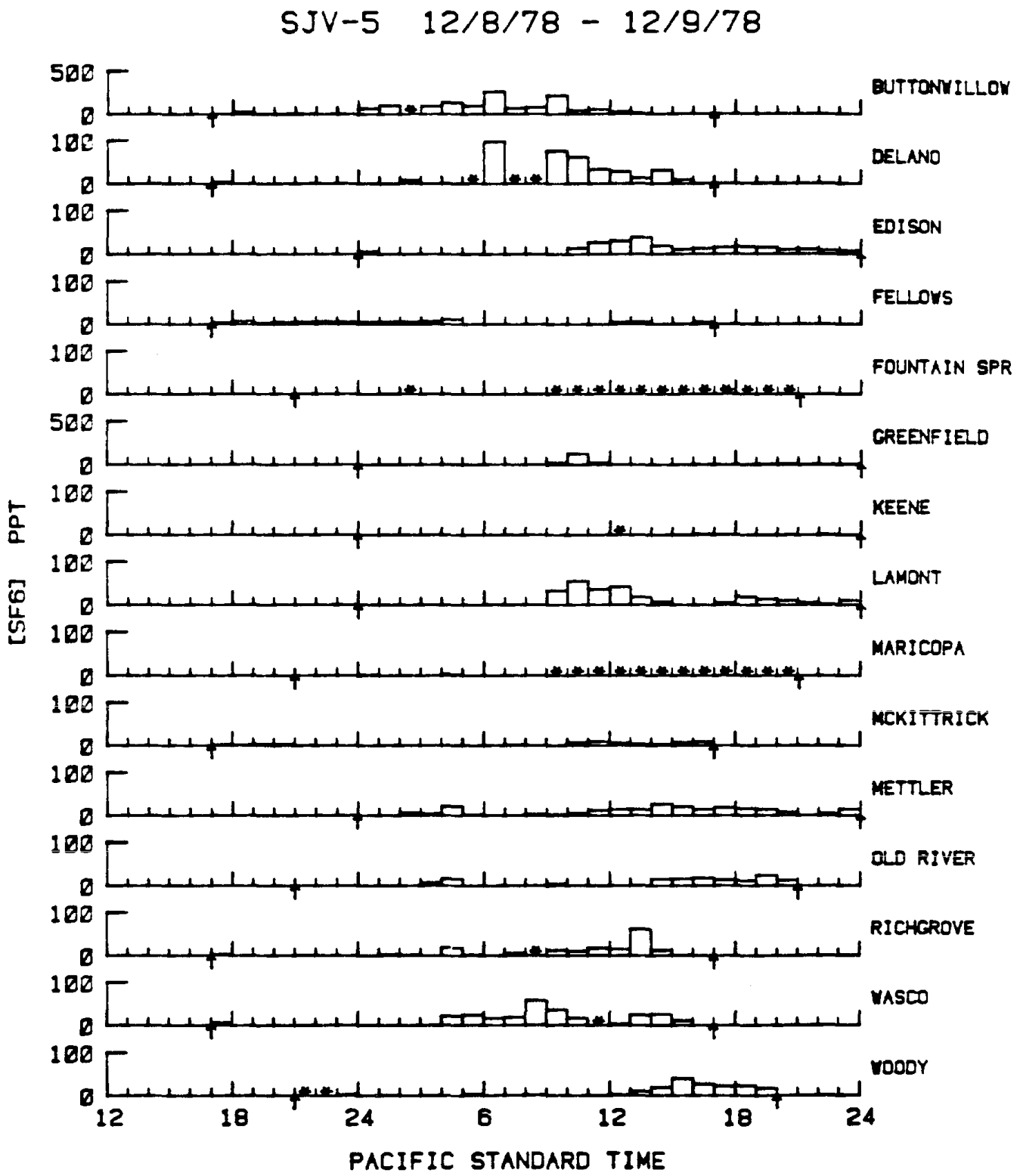
SF_6 was first detected during Automobile Traverse 1-1 along Highway 33, at a location 12-15 miles west-northwest of Lost Hills. The SF_6 plume was encountered about 1630 PST, about 2-1/2 hours after the start of the release. Thus the transport speed of the tracer towards the west was at least about 5 mph. Other traverses, notably Traverses 2-3 and 3-3, detected SF_6 north and west of the release site. During Traverse 2-3 an average SF_6 concentration of 25-30 ppt and a peak concentration of about 50 ppt were detected near Cottonwood and Polonio Passes. Both passes are located near Cholome, about 30 miles northwest of Lost Hills. The tracer plume was apparently relatively well-mixed over a zone about 20 miles wide and 30 miles long. The maximum afternoon mixing height was about 3000 ft on the day of the release. Assuming that the tracer was well-mixed within this volume accounts for about 470 pounds of SF_6 or about 75 percent of that originally released. While the exact amount of SF_6 within this plume cannot be accurately determined, the above mass balance calculation suggests that most of the SF_6 was indeed transported northwest of the release site. This was apparently true even though the surface winds at the release site shifted from southeasterly to northeasterly to westerly during the course of the release. It should be noted that predictive analyses of pollutant transport and dispersion must often be based only on surface wind data. During this experiment, however, the shallow surface winds did not accurately indicate the tracer transport path.

Transport by nighttime drainage winds

While the surface winds apparently did not transport the bulk of the released tracer, some SF_6 was transported southeast of the release site. The northwesterly wind that developed at the surface near the end of the release was a nighttime drainage wind that typically consists of stable air only weakly coupled with the synoptic scale flow. Thus the SF_6 released into the drainage winds was transported towards the southeast and not strongly influenced by the easterly winds aloft. Due to limited vertical mixing, concentrations in the tracer plume transported towards the southeast tended to be higher than corresponding concentrations in the tracer plume transported to the northwest. 727 ppt was detected about 2100 PST near Buttonwillow, 20 miles southeast of the release site. As shown in Figure 3.5.14, SF_6 was detected at Buttonwillow throughout the night. Part of the SF_6 detected at Buttonwillow during the early morning hours of 12/9/78 was probably tracer that originally had been transported towards the northwest. The drainage condition returned the surface layer of SF_6 back towards the release site and the center of the valley. By early morning on 12/9/78, SF_6 was detected at a number of fixed sampling sites throughout the San Joaquin Valley. Data from all of the fixed sampling sites is collected in Figure 3.5.14 and the location of each site is shown in Figure 3.5.15. Beginning at 0400 PST, about 20 ppt of SF_6 was detected at the south-central valley sampling sites of Mettler and Old River. At the same time similar concentrations were detected north of Bakersfield at Wasco and Richgrove. At Wasco, SF_6 was detected beginning about 0400, 12/9/78.

Transport eastward of southern plume - day following release

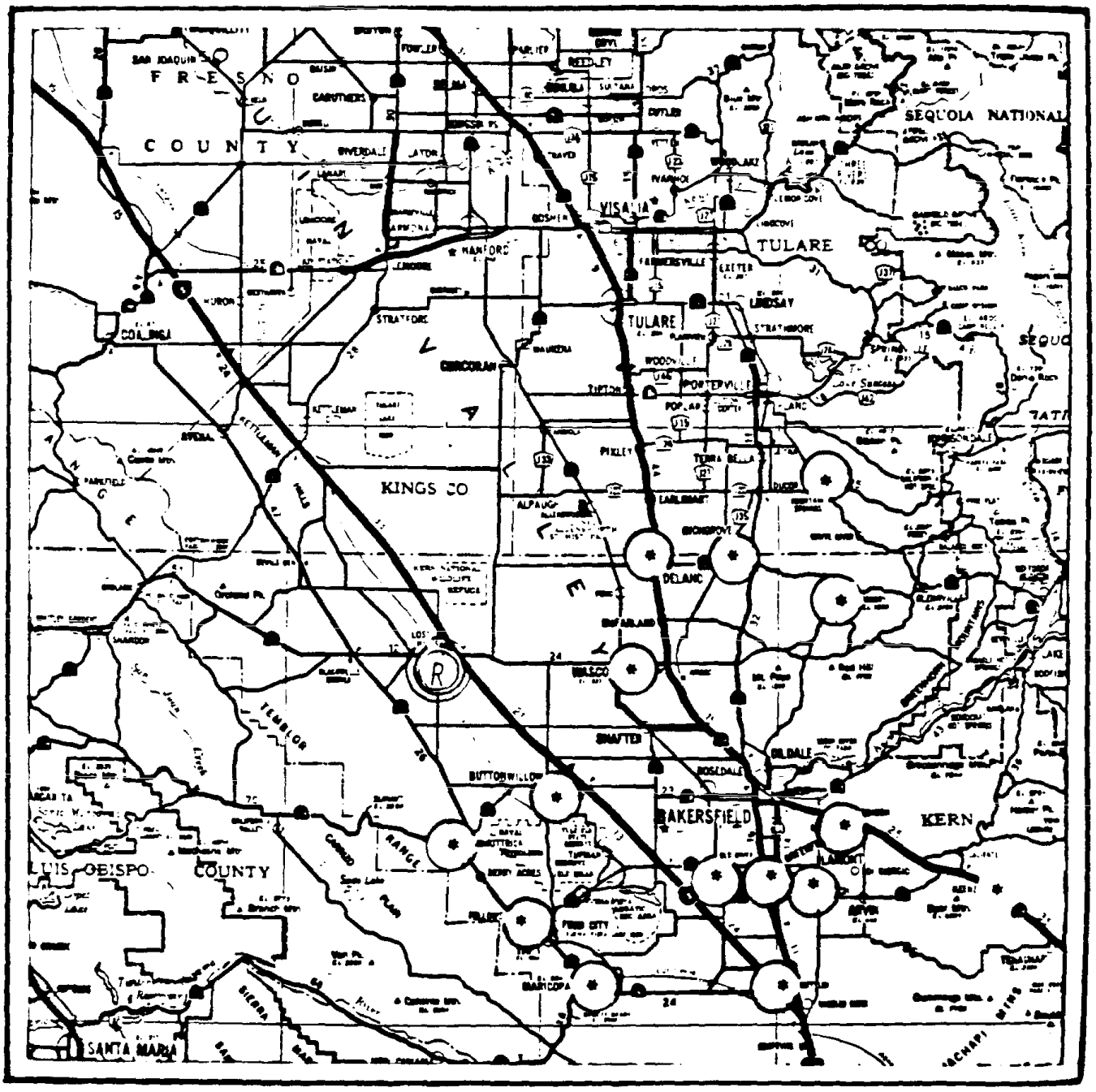
As the day following the release (12/9/78) progressed, the SF_6 was detected farther and farther east. Between 0900 and 1200 PST, SF_6 was detected at Greenfield, Lamont, Edison and Mettler, all south and/or east of Bakersfield. Between 1000 and 1100 PST, 38 ppt was detected at Greenfield. The maximum concentrations detected at the other sites were 55 ppt between 1000 and 1100 PST at Lamont, 38 ppt between 1300 and 1400 PST at Edison, and 26 ppt between 1400 and 1500 PST at Mettler. Automobile and airplane traverses southwest of Bakersfield during mid and late afternoon, suggested that the tracer concentrations were essentially uniform over the entire region at about 15 ppt. This SF_6 accounts for at least a third of the SF_6 originally released.



RELEASE: 630 LBS SF6 AT LOST HILLS
RELEASE TIME: 1400-2030 PST, 12/8/78

• INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.5.14



(*) INDICATES SAMPLER LOCATIONS

(R) IS THE RELEASE SITE

Figure 3.5.15

Transport eastward of northern plume - day following release

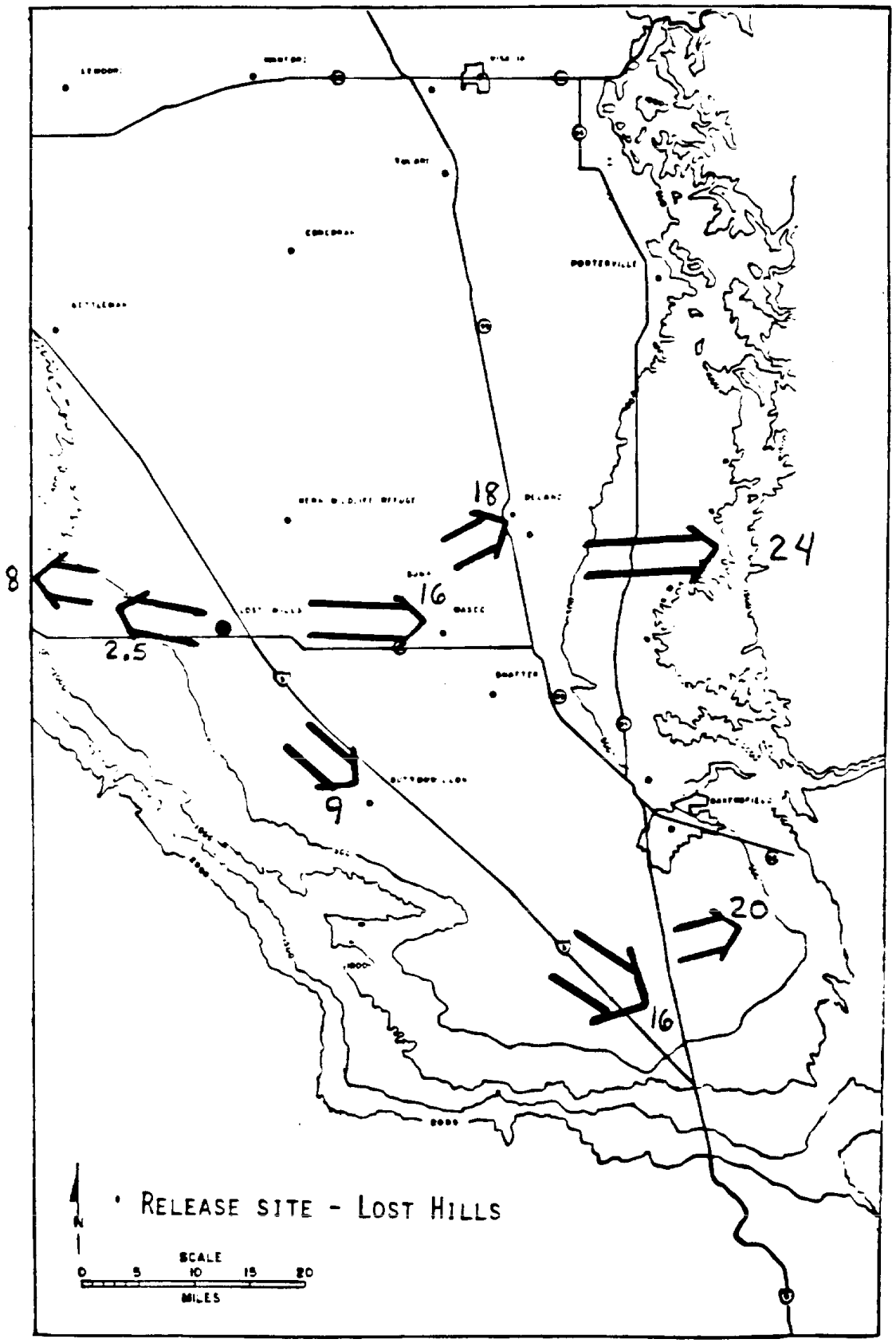
Some of the tracer not accounted for south of Bakersfield was detected towards the north. Between 0800 and 0900 PST, 58 ppt was detected at Wasco. SF_6 was also detected at Delano between 0600 and 1600 PST, at Richgrove between 0900 and 1500 PST, and at Woody between 1400 and 2000 PST. The highest concentration among these sites was 97 ppt, detected at Delano between 0600 and 0700 PST. It was not possible to make an accurate mass balance estimate, but in light of the concentration levels detected, the amount of tracer in this region was probably about the same or more than the amount detected in the region south of Bakersfield.

Carryover into second day after release

During the early morning of 12/10/78, an average concentration of between 5 and 10 ppt was detected near the center of the valley along Highway 43. By about noon, Traverse 5-1 found roughly the same levels over the entire southwestern end of the San Joaquin Valley. The maximum concentrations detected on this day are slightly less than an order of magnitude lower than those detected on 12/9/78. It is not clear whether the concentration decrease should be attributed to transport out of the valley or dispersal within the boundaries of the valley. It is clear, however, that a measurable amount of the tracer released two days previously remained within the valley.

Summary

During this experiment, SF_6 was released from Lost Hills on the west side of the San Joaquin Valley. The tracer experiment was intended to illustrate the transport and dispersion of airborne contaminants emitted primarily from the surrounding oilfields. An overview of the tracer transport can be found in Figure 3.5.16. During the afternoon of the release, the winds above the release site transported most of the tracer towards the northwest. As the nighttime drainage flow developed, SF_6 was transported from the release site towards the southeast. In addition, the nighttime drainage flow returned a significant portion (if not all) of the SF originally transported towards



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (1400 PST, 12/8/78)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.5.16

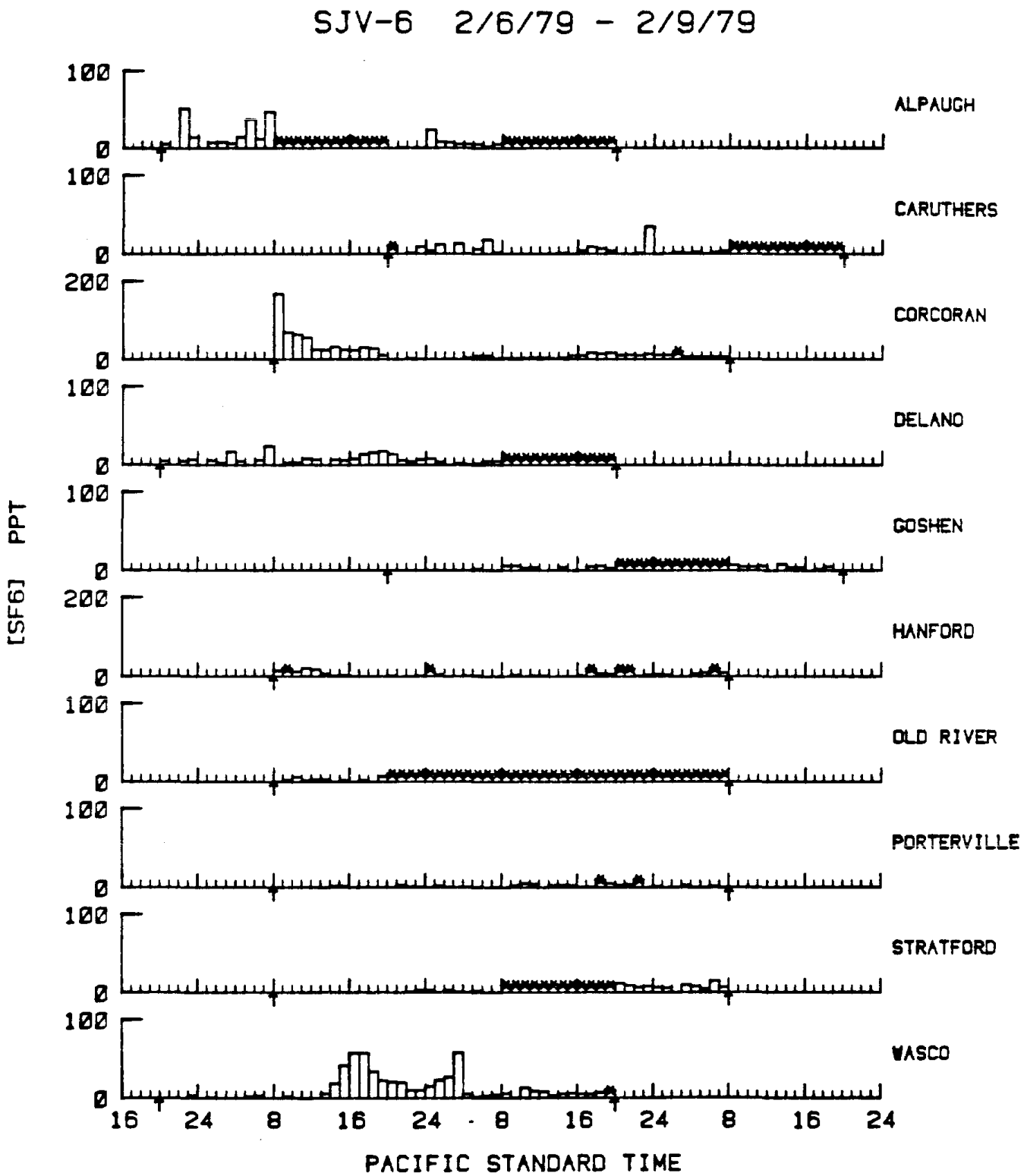
the northwest. As in several of the preceding tests, the tracer was found to be transported from one side of the San Joaquin Valley to the other. SF_6 concentrations as high as 128 ppt were detected southeast of Bakersfield (at Greenfield) on the morning of the day following the release. By mid-afternoon on the day after the release, the tracer appeared to be spread over wide areas at concentrations of the order of 15-20 ppt. The area south and west of Bakersfield was essentially well-mixed at about 15 ppt. This accounts for at least about a third of the original amount of tracer released. Similar concentrations were also found in a large area north of Bakersfield, including Woody, Wasco, Delano and Richgrove. It thus appears that at least half of the tracer released at Lost Hills on 12/8/78 was still within the boundaries of the San Joaquin Valley during the afternoon of 12/9/78. Low SF_6 concentrations were also detected over essentially the entire southern San Joaquin Valley on 12/10/78.

3.6 Tracer Test 6

Release Location: Lost Hills, Kern County
Time and Date: 2000 PST, 2/6/79 - 0800, 2/7/79
Amount: 53 pounds of SF_6 per hour
Release conducted during light southwesterly drainage winds. Entire test period characterized by relatively stagnant conditions.

Extent of initial northward transport

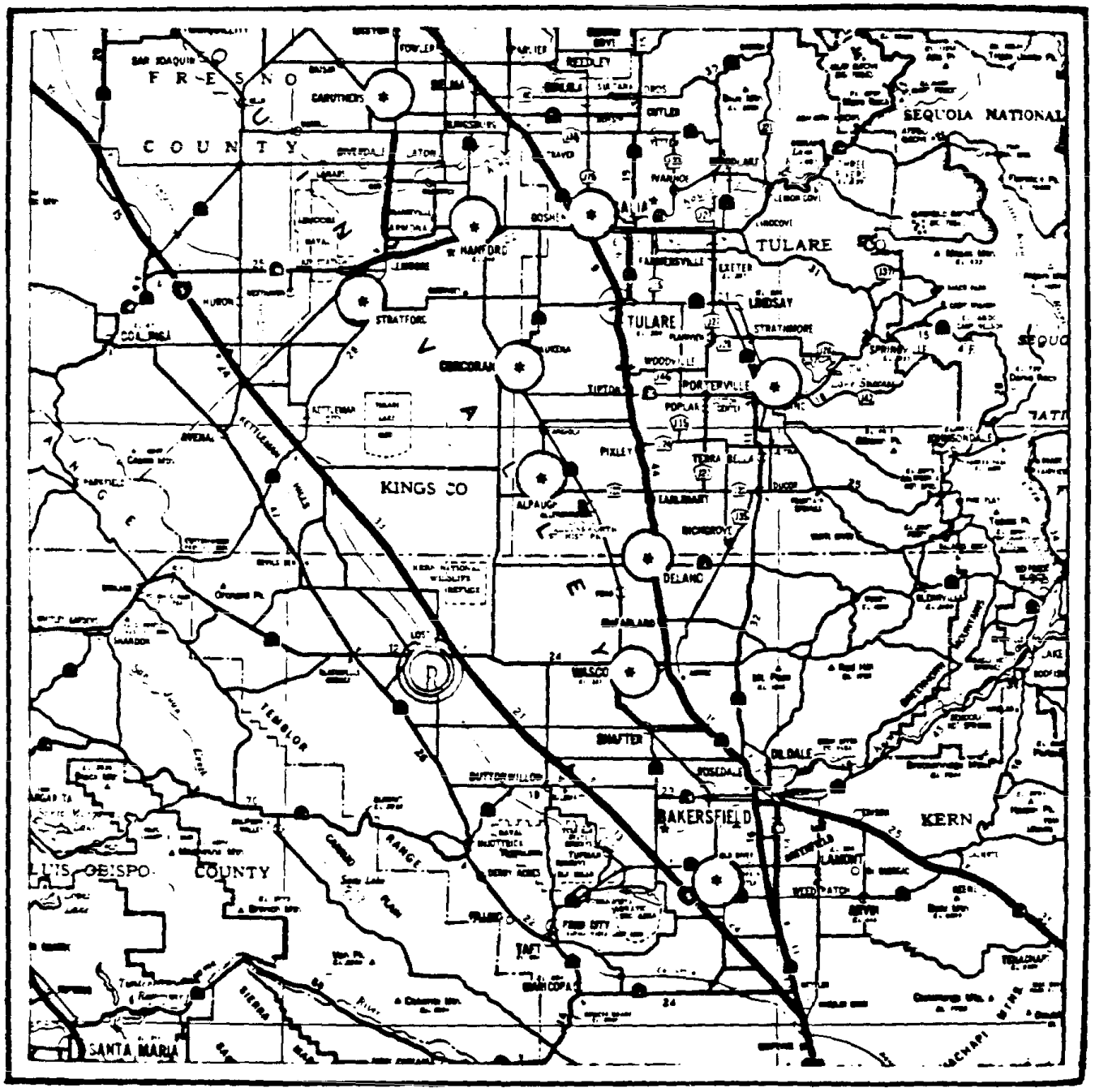
SF_6 was first detected by an hourly averaged automatic sampler at Alpaugh, about 22 miles northeast of the Lost Hills release site. All of the hourly-averaged board data are collected in Figure 3.6.1 and a map showing the locations of these sites is presented in Figure 3.6.2. The arrival of SF_6 at Alpaugh between 2200 and 2300 PST suggests a transport velocity of between 7 and 11 mph. Surface wind speeds at Lost Hills, however, were between 3 and 5 mph throughout the night. Only surface winds were monitored during this test so it was not possible to determine if the enhanced transport speed could be attributed to winds aloft. SF_6 was again detected at Alpaugh between 0400 and 0800 PST on 2/7/79. The maximum normalized SF_6 concentration was 47 ppt (130 ppt/lb-mole SF_6 released per hour), detected between 0700 and 0800 PST. After 0800, no samples were taken at Alpaugh due to instrument failure. At 0800 PST, however, an automatic sampler was started at Corcoran, 15 miles north of Alpaugh. During the first hour of operation 167 ppt of SF_6 (460 ppt/lb-mole released/hr) was detected, suggesting that Corcoran was close to the centerline of the SF_6 plume. Between 0800 and 1300 PST, SF_6 concentrations as high a 20 ppt (55 ppt/lb-mole released/hour) were detected at Hanford, about 15 miles north of Corcoran. The arrival of SF_6 at Hanford was assumed to be about 0800 PST, although this could not be confirmed since the sampler began operation at that same time. Assuming an 0800 PST sampling time, the mean transport speed of the tracer from Lost Hills was about 4 mph, consistent with the surface wind speed measurements at Lost Hills.



RELEASE: 635 LBS SF6 AT LOST HILLS
RELEASE TIME: 2000-0800 PST, 2/6/79

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.6.1



INDICATES SAMPLER LOCATIONS

R IS THE RELEASE SITE

Figure 3.6.2

Transport and dispersion of tracer on day following the release (2/7/79)

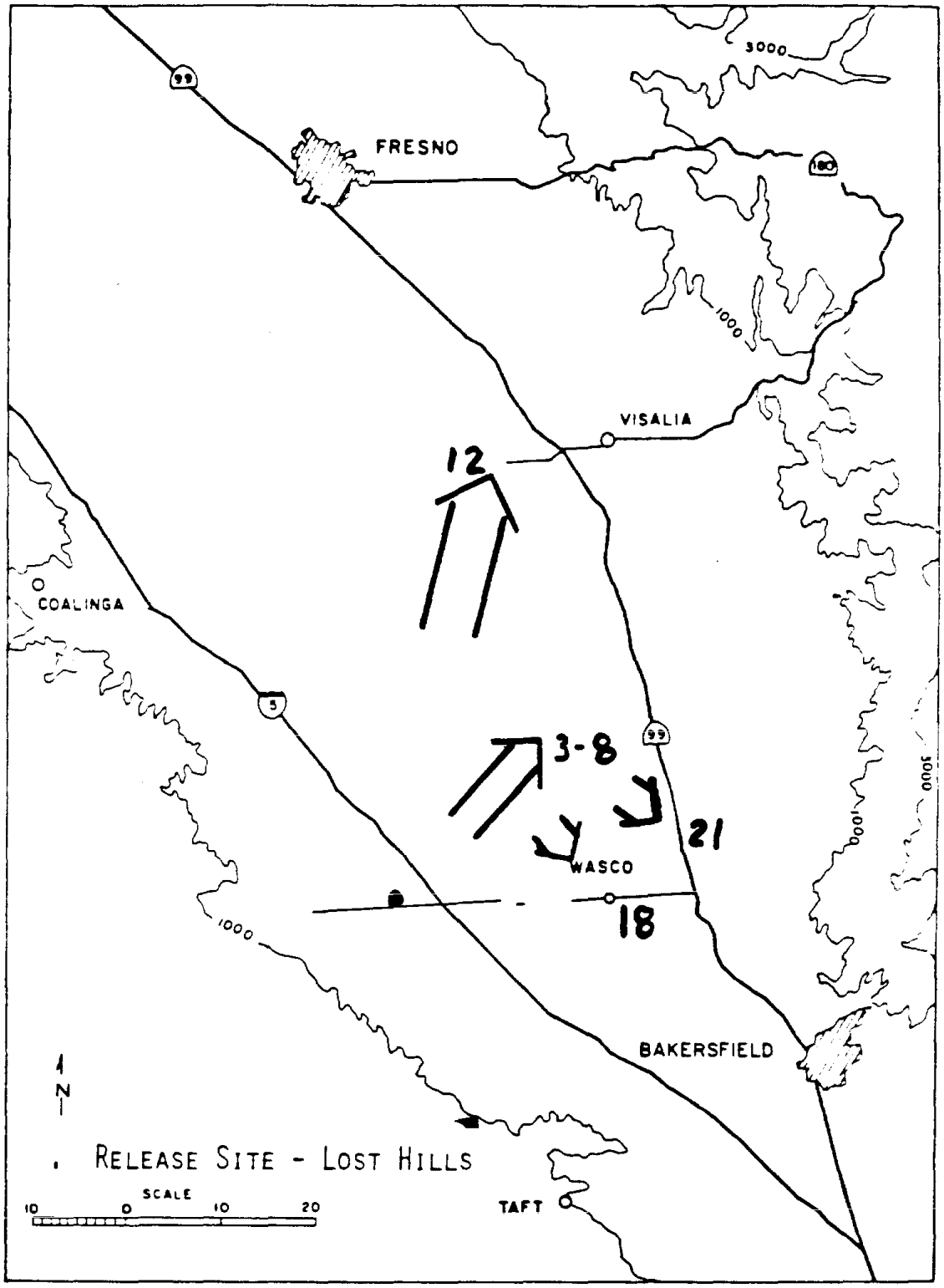
At no time during the course of this experiment were significant concentrations of the tracer detected farther north than Hanford. During the afternoon following the tracer release (2/7/79), the SF_6 was apparently transported back towards the southern end of the San Joaquin Valley. SF_6 was detected at Corcoran between 0800 and 2000 PST. By 1400 PST, SF_6 was detected at Wasco, directly east of the release site. SF_6 concentrations in excess of 10 ppt were detected at Delano, north of Wasco along Highway 99, between 1700 and 2100 PST. No automobile traverse data were available during the day following the release. A large group of syringes were contaminated by exposure to high concentrations of SF_6. The contamination was not detected until after a number of the syringes were used. Fortunately, it was possible to ascertain which of the syringes were stored together and thus separate reliable from questionable data. All results reported here are from data in which there is a high degree of confidence.

Location of tracer on 2/8-9/79

While much of the data collected during this experiment had to be excluded from the analysis due to sample contamination, it was possible to draw some generalizations about the location of the tracer on the second and third day following the tracer release. At Corcoran, an average SF_6 concentration of 13 ppt was detected between 1700 PST, 2/8/79 and 0200 PST, 2/9/79. The SF_6 was spread over a very wide area, however, as evidenced by its detection at low, but non-zero, concentrations over the entire half of the San Joaquin Valley lying south of Highway 198 that passes through Hanford. During Traverse 3-1 and 3-2 (late afternoon 3/9/79), SF_6 levels between 10 and 20 ppt were consistently found east of Bakersfield. These levels were detected as far east as Tehachapi, near the ridgeline separating the San Joaquin Valley from the Mojave Desert. Because most of the SF_6 levels detected during these automobile traverses were less than 5-10 ppt, it was not possible to accurately estimate the mass of SF_6 remaining within the valley.

Summary

During this experiment, tracer released from northwestern Kern County was transported by a southwesterly wind into several sites in Kings County and into the western edge of Tulare County. An overview of the initial transport of the tracer is presented in Figure 3.6.3. During the day following the release, the tracer remained north and east of the release site as evidenced by its detection at Wasco, Delano and Corcoran. The tracer may have been transported towards the southern end of the San Joaquin Valley, but a limited amount of data was available to validate this. On the second day following the release, the tracer was detected at low concentrations over the entire southern half of the San Joaquin Valley. The highest concentrations detected during this day were about 10-15 ppt east of Bakersfield, near Tehachapi. This suggests that much of the tracer was slowly transported south of the release point and towards the Tehachapi Mountains. The tracer was clearly transported across the nighttime convergence zone that typically occurs in mid-valley due to drainage flows from mountains on both sides of the valley. Due to limited amounts of data, it was not possible to determine the amount of tracer that was transported out of the valley on any given day. Low but detectable concentrations of SF_6 were found, however, on 2/10/79, more than three full days after the beginning of the release. This indicates that carryover of pollutants into days subsequent to the release can be significant during stagnant winter conditions in the San Joaquin Valley.



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (2000 PST, 2/6/79)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.6.3

3.7 Tracer Test 7

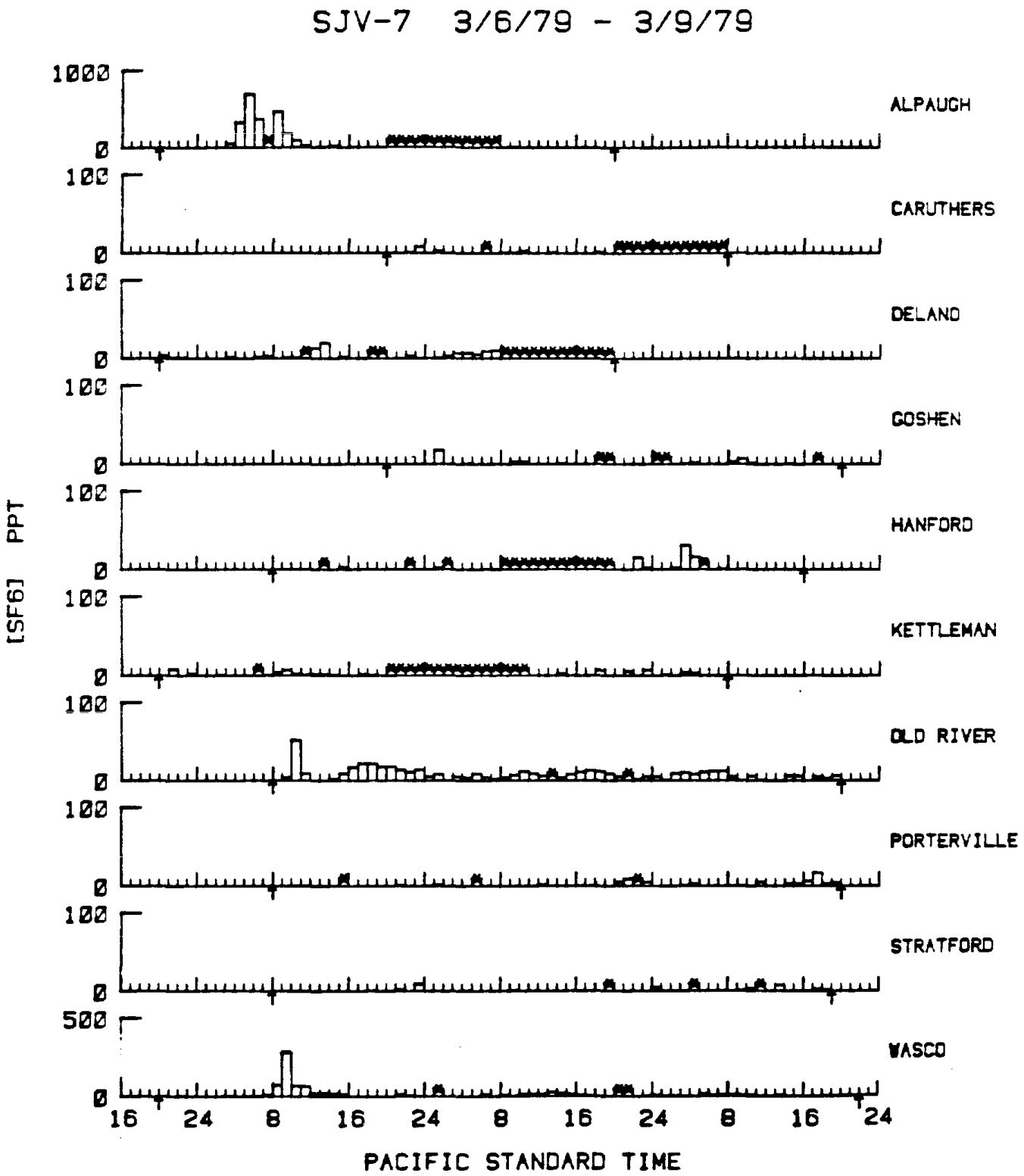
Release Location: Lost Hills, Kern County
Time and Date: 2030 PST, 3/6/79 - 0800, 3/7/79
Amount: 59 pounds of SF_6 per hour
Release conducted during light southwesterly drainage winds. Entire test period characterized by relatively stagnant conditions.

Extent of initial northward transport

SF_6 was initially transported by the southwesterly drainage winds that persisted throughout the release. The tracer was first detected at Alpaugh between 0300 and 0400 PST, 3/7/79. The data collected at this and all other hourly-averaged sampling sites are presented are Figure 3.7.1 and a map showing the locations of these sites is presented in Figure 3.7.2. The detection of SF_6 at Alpaugh corresponded to a mean transport speed of about 3 mph, which is consistent with the winds measured at the release site. Hourly-averaged SF_6 concentrations as high as about 700 ppt (1700 ppt/lb-mole SF_6 released/hr) were detected at Alpaugh. The six hour average concentration between 0400 and 1000 PST was 410 ppt. Beginning about 0700 PST, SF_6 was detected at Wasco, directly east of the release site. The arrival of SF_6 at Wasco corresponded to a net transport speed of slightly less than 2 mph (based on the straightline distance between Lost Hills and Wasco - about 22 miles). About 280 ppt (700 ppt/lb-mole released/hr) of SF_6 was detected at Wasco between 0900 and 1000 PST.

Day after release (3/7/79)

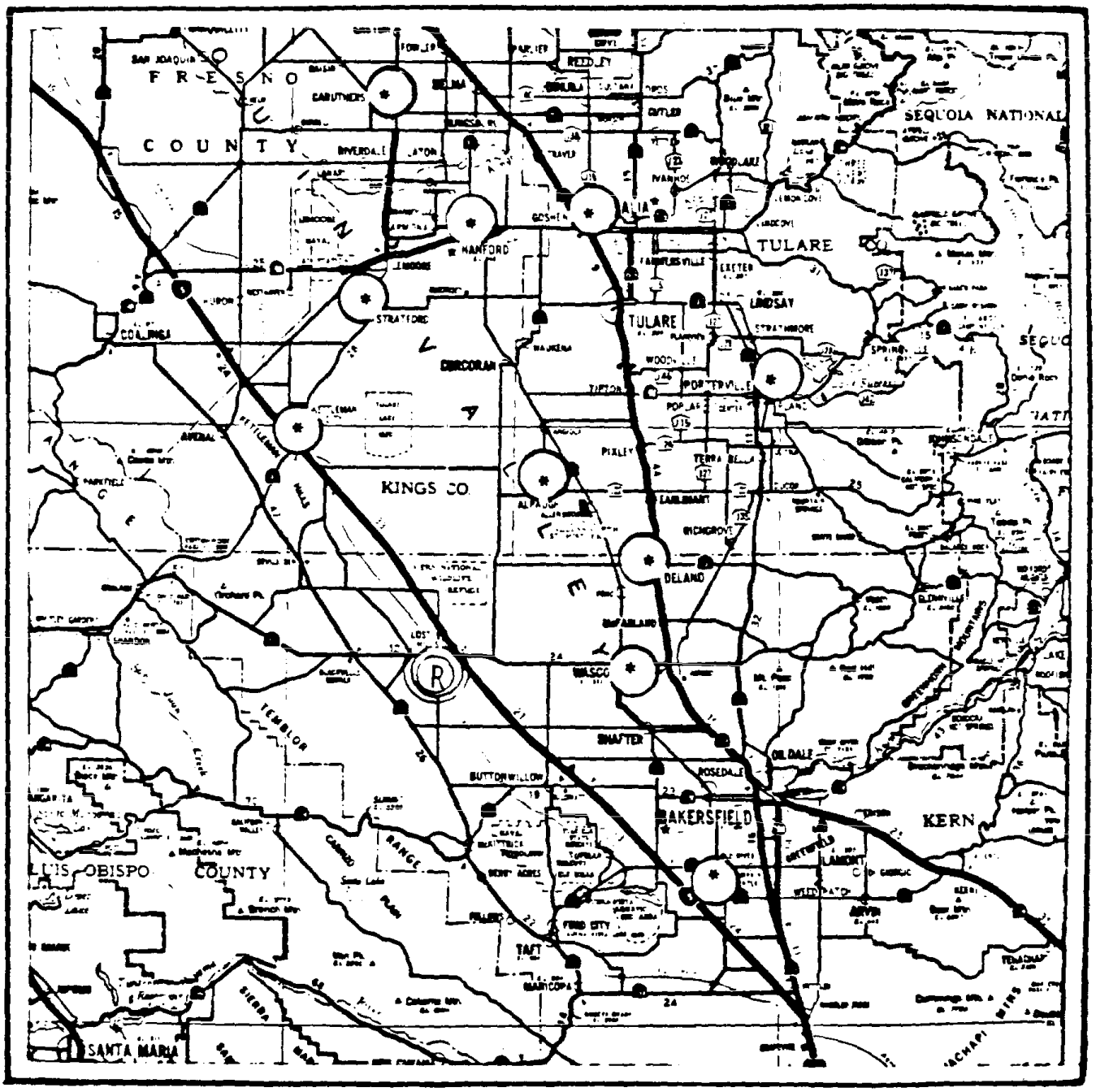
During the day after the release (3/7/79), SF_6 was transported southward to the southern limit of the San Joaquin Valley. This transport was documented by both automatic fixed site samplers and by automobile traverse samples. As shown in Figure 3.7.2, a short-lived tracer plume passed through Old River, south and west of Bakersfield with a peak of 52 ppt between 1000 and 1100 PST. While only a single fixed site sample detected a significant amount of SF_6, automobile traverses in the same area between 1100 and 1300



RELEASE: 680 LBS SF6 AT LOST HILLS
RELEASE TIME: 2030-0800 PST, 3/6-7/79

* INDICATES MISSING DATA
ARROWS INDICATE BOUNDS OF SAMPLING PERIOD

Figure 3.7.1



(•) INDICATES SAMPLER LOCATIONS

(R) IS THE RELEASE SITE

Figure 3.7.2

PST (1-2 and 2-1) detected SF_6 concentrations between 30 and 60 ppt. Higher SF_6 concentrations were detected a little farther north and closer to the western edge of the valley. About 1300 PST, during Traverse 2-1, SF_6 concentrations as high as 360 ppt were detected near Lost Hills. About 1630 PST, during Traverse 1-4, SF_6 concentrations as high as about 160 ppt were detected just west of Buttonwillow along Highway 33. While the highest tracer concentrations were found on the western side of the valley, significant amounts of the tracer were in the center and southeastern edge of the San Joaquin Valley. An average of 17 ppt was detected at Old River between 1600 PST and midnight. As a further indication of SF_6 transport out of the region north and east of the release site, the tracer concentrations at Wasco steadily decreased throughout the day, and none was detected after 1600 PST. The tracer detected at Old River throughout the evening was probably SF_6 transported south from the region around Wasco.

Second day after release (3/8/79)

On the second morning after the tracer release the tracer was essentially well-mixed over a large portion of the southern San Joaquin Valley. Between 1230 and 1500 PST, during Traverse 2-5, an average SF_6 concentration of 20 ppt (std dev +/-4 ppt) between Delano and Taft. This suggests that the tracer was essentially well-mixed over a zone about 40 miles long and 25 miles wide. The maximum afternoon mixing height on this day was estimated from a temperature sounding at Fresno to be about 3000 ft above ground level. 20 ppt SF_6 well-mixed within this volume accounts for approximately 95 percent of the total mass of SF_6 released. While this calculation is subject to large uncertainties it clearly indicates that the majority if not essentially all, of the SF_6 originally released on the night of 3/6/79 was still within the southern San Joaquin Valley during the day of 3/8/79.

Third day after release (3/9/79)

Early in the morning of 3/9/79, SF_6 was detected at Hanford near the center of the San Joaquin Valley. A maximum hourly-averaged concentration of 31 ppt was detected between 0300 and 0400 PST. The tracer was apparently

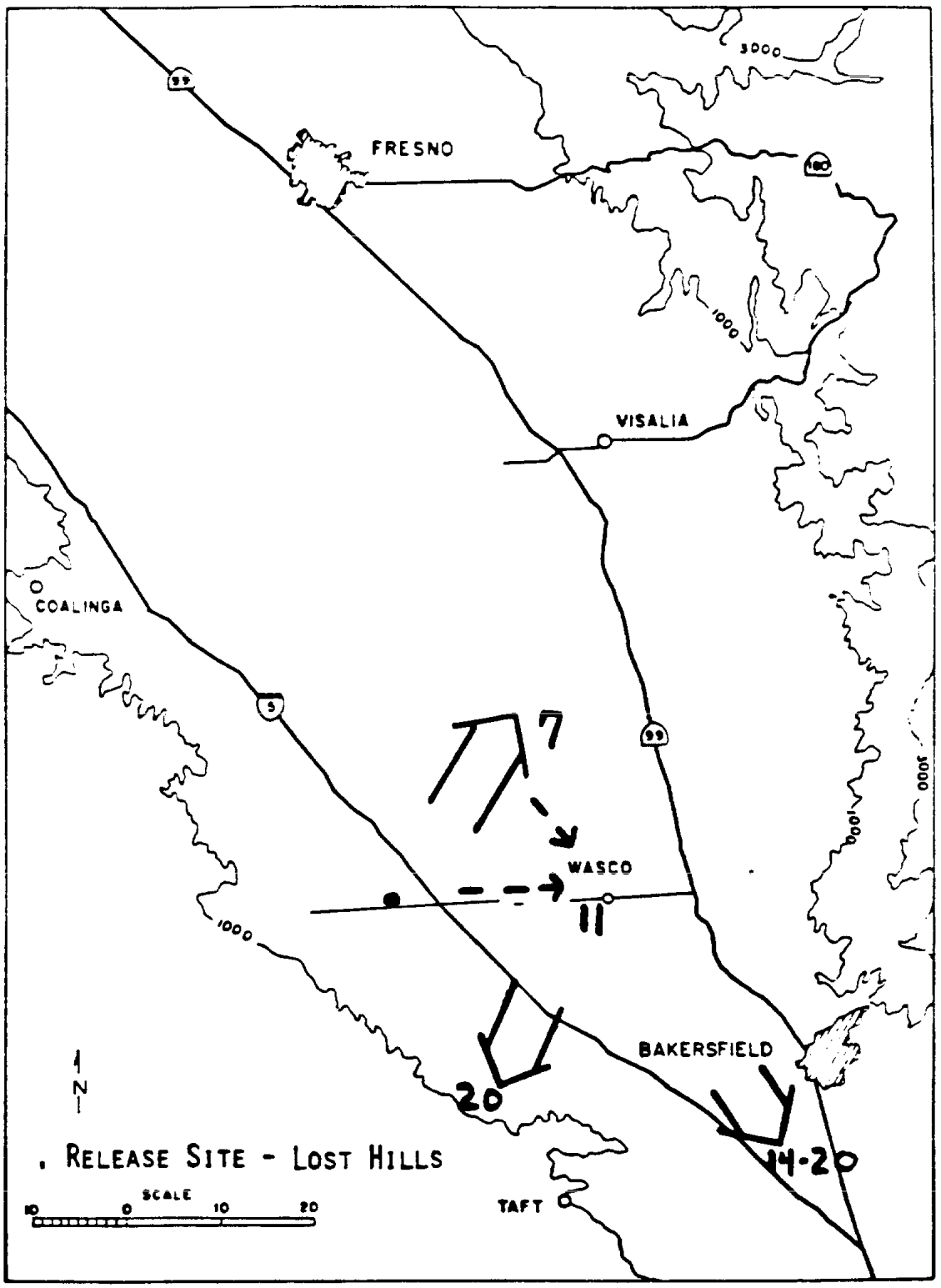
transported towards the north-central valley by the nighttime drainage winds that typically converge in the center of the valley. During the afternoon of 3/9/79, SF_6 concentrations of 5-10 ppt were detected throughout the southern San Joaquin Valley. This concentration is slightly less than half that detected on the previous day. During the early afternoon, automobile traverses indicated that the tracer concentrations in the center of the valley were lower than those on the west and east sides of the valley. Neglecting all concentrations below 5 ppt, almost 50 percent of the tracer originally released can be accounted for within the valley. This calculation is based on a 4000 ft maximum mixing height estimated at Fresno, and a 900 sq. mi. estimate of the well-mixed area. The area estimate was made by assuming that SF_6 was well-mixed over a simple rectangle between Bakersfield and Wasco and another simple rectangle between Maricopa and Buttonwillow. The perimeter of the rectangles was suggested by the automobile traverse data. At concentrations below 10 ppt, it is very difficult to accurately calculate a mass balance, but the estimated mass balance of 50 percent is probably within +/- 25 percent of the actual amount of tracer remaining within the valley.

Fourth day after the release (3/10/79)

During the fourth day after the release (3/10/79), SF_6 was detected at low but non-zero concentrations over the entire San Joaquin Valley from just south of Bakersfield to as far north as about Corcoran. The average SF_6 concentration of this magnitude could be in error by a factor of 2 or more due to limitations of the analytical technique. The detection of non-zero SF_6 levels nearly four days after the start of the tracer release, however, clearly indicates that the mean residence time of airborne pollutants within the southern San Joaquin Valley during stagnant winter conditions is well in excess of one day.

Summary

During this experiment, SF_6 released from Lost Hills during a nighttime drainage condition was transported towards the valley center. During the subsequent day, afternoon upslope winds transported the tracer towards the southwest and the southeast. An overview of the tracer transport path is presented in Figure 3.7.3. This transport pattern was in evidence during every day of the test, nighttime transport towards the north and center of the valley, daytime transport



ARROW POINT INDICATES OBSERVED TRACER LOCATIONS
NUMBERS REFER TO HOURS AFTER RELEASE START (2030 PST, 3/6/79)
- - - UNCERTAIN TRANSPORT PATH

Figure 3.7.3

towards the south and edges of the valley. The limit of northward transport appeared to be near Hanford along Highway 198, while the southward (and outward) limit of transport was the surrounding mountain slopes or beyond. The Wasco hourly-averaged sampler (Figure 3.7.4) indicates the diurnal motion of the tracer in that tracer was detected at this location at roughly 24-hour intervals. On the second day after the release (3/8/79), essentially all of the tracer originally released could be accounted for within the valley. During the next day it appeared that at least 50 percent of the tracer released could be accounted for within the valley. Thus roughly half of the tracer originally released could be accounted for about 60 hours after the end of the release. On subsequent days it was not possible to make a definitive estimate of the amount of SF_6 that remained within the valley, but small amounts of the tracer were detected as long as four days after the start of the release.

By the second day after its release, the tracer was essentially well-mixed over large zones. As shown by the Old River hourly-averaged sampler (Figure 3.7.5), the tracer data suggested that the well-mixed concentrations decreased by a factor of about 2 during each day of the experiment. Thus under similar meteorological conditions, the contribution to ambient concentrations of a conserved pollutant from an area-wide (regional) source decreases by about a factor of 2 for every day after the pollutants release. The tracer data can thus be used directly to form a simple box model of pollutant concentrations in the southern valley during stagnant conditions. For example, assume that a certain continuous source (or sum of sources) could lead to ambient concentrations of some pollutant of 1 ppm, if the total day's output were well-mixed over the entire southern valley. During stagnant atmospheric conditions, the well-mixed ambient concentration on the second day would be 1.5 ppm, while on the third day 1.75 ppm would be found. It should be noted that this simple model which assumes that the carryover concentrations are 1/2 of the previous days concentrations, will never predict an ambient concentration more than double that which would be expected with no carryover.

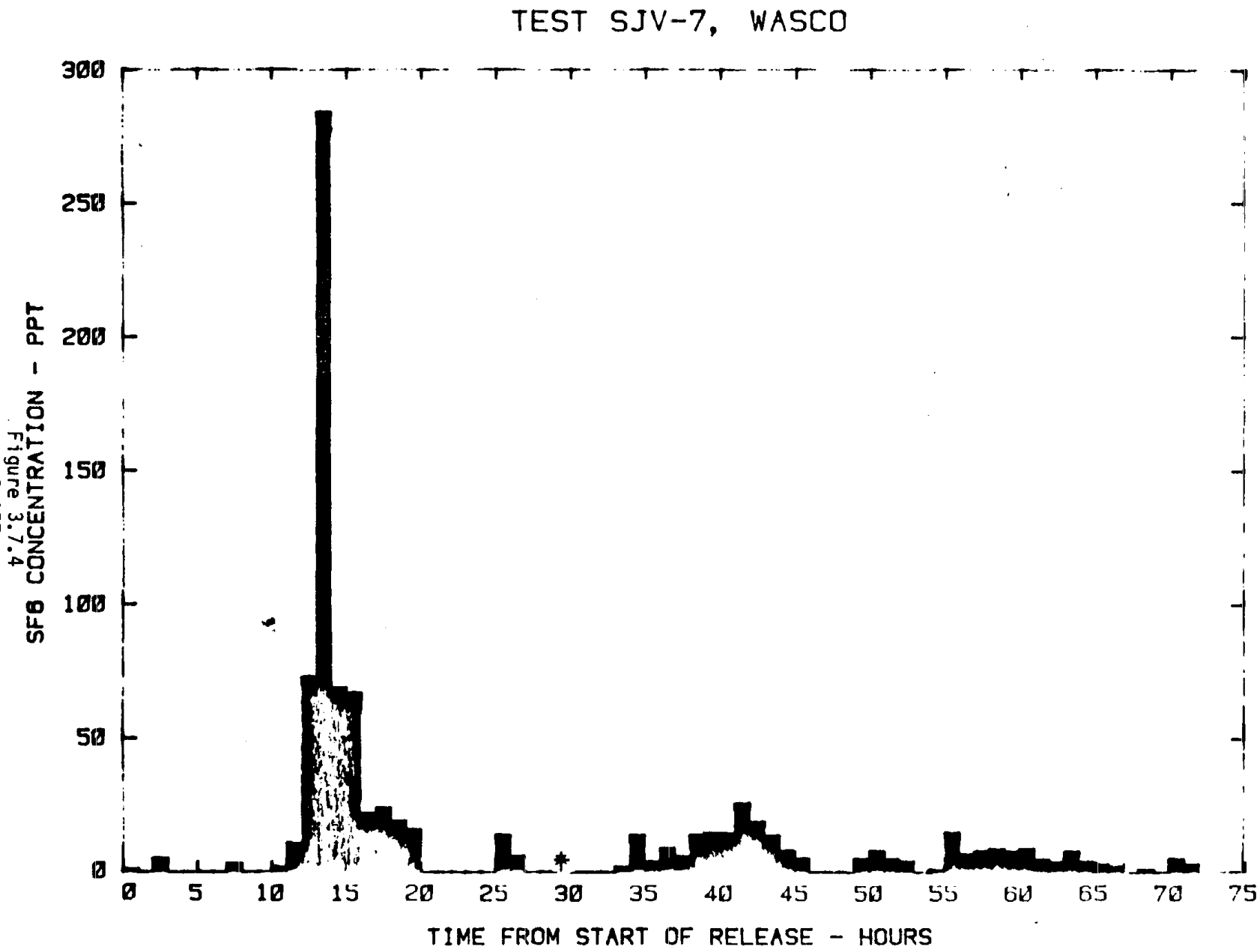

TEST SJV-7, WASCO
SF6 CONCENTRATION - PPT
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
TIME FROM START OF RELEASE - HOURS

Figure 3.7.4

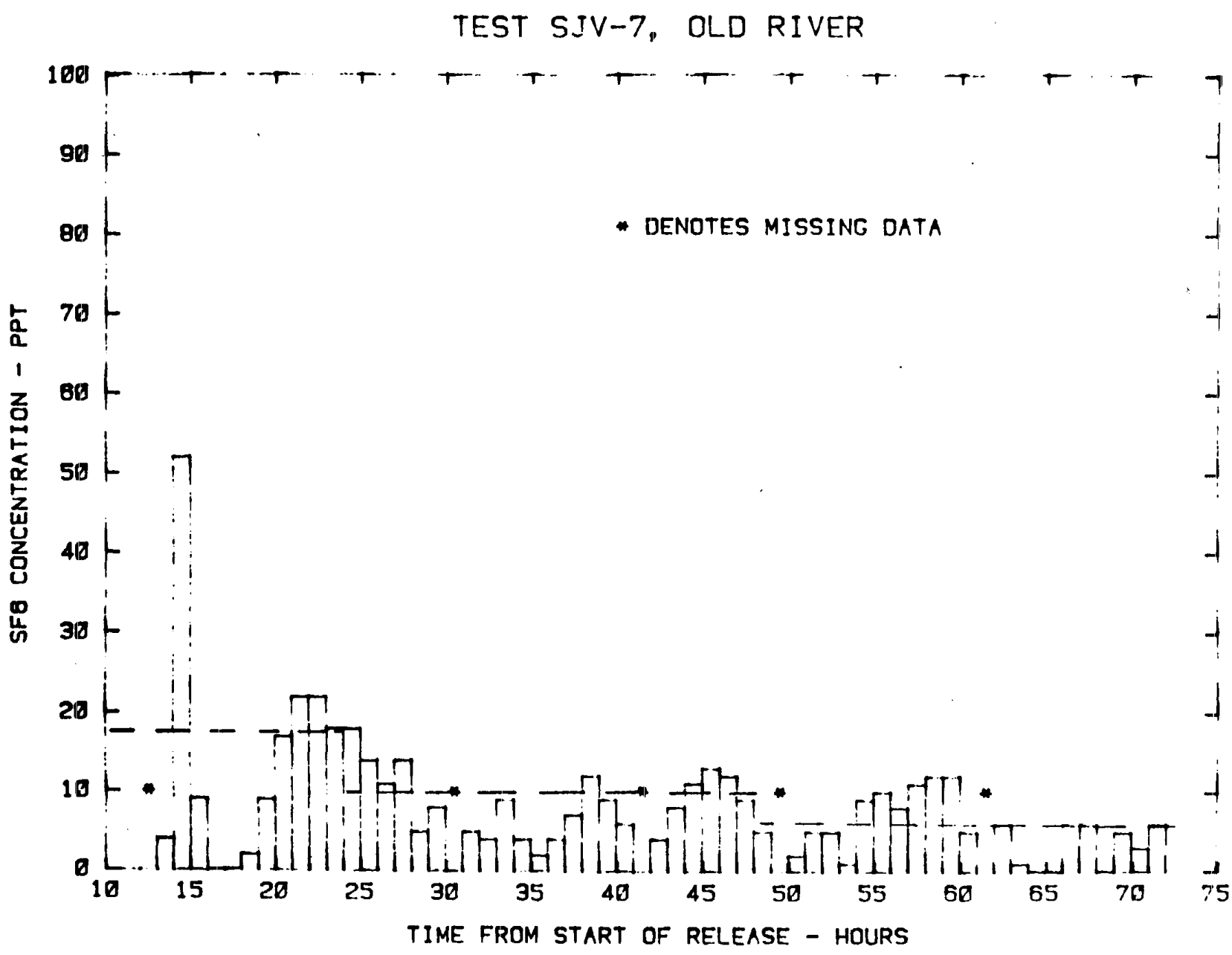

TEST SJV-7, OLD RIVER
* DENOTES MISSING DATA
SF6 CONCENTRATION - PPT
100
90
80
70
60
50
40
30
20
10
0
10
15
20
25
30
35
40
45
50
55
60
65
70
75
TIME FROM START OF RELEASE - HOURS

Figure 3.7.5

4. Summary of Individual Tracer Tests

Test 1 - Chowchilla, November 15, 1978 (1100-1600 PST)

Meteorology
- Stabilizing atmosphere, weak synoptic winds.
- Winds at the release site light and southerly, shifting to northwesterly after release.

Air Quality
- Low visibilities and low pollutant concentrations.

Tracer
- Initial transport northward. Generally light and variable winds led to dispersal with little net transport.
- Slow transport southward during night and following morning.
- Net transport speed to Fresno of 1.5 mph.
- Mass balance, evening of 11/16/78
  - 50 ppt, 10 miles x 35 miles x 2000'
- Some tracer detected near Delano and Wasco, 20 hours after start of release (5 mph transport speed).

Test 2 - Fresno, November 18, 1978 (1200-1700 PST)

Meteorology
- Light synoptic scale flow, near normal temperature conditions aloft and at surface.
- Winds at the release site southerly during afternoon, easterly through 0200 then northwesterly.
- Southerly winds aloft (1000') until day after release.
- Shallow mixing layer $\leq$ 1000 ft.

Air Quality
- Slightly higher ozone concentrations than during previous test (0.07 ppm maximum Lost Hills, McKittrick).
- Fresno urban plume
  - Background 45 ppb ozone, 20 ppb NO_x
  - Ozone deficits within plume
  - Low SO_2
  - Afternoon 50 ppb background NO_x within plume

Tracer - Initial transport northward with stability class B or C.
- Near end of release, easterly drainage winds led to transport towards the center of the valley.
- Transport southward during night and following morning.
- Apparently all or most of tracer detected within 30 miles of Fresno on morning after release.

Test 3 - Bakersfield, November 25, 1978 (1200-1700 PST)

Meteorology - Weak frontal movement through the valley on previous day leading to better mixing and higher visibilities. 850 mb temperature 7°C below 5-year average.
- Light winds (though stronger than previous tests), northwesterly at release site consistent with flow up and over the Tehachapis.
- Increasing stabilization beginning around 1900, followed by drainage flows until 1000 the next day.

Air Quality - Generally low ozone and other pollutant concentrations.
- Background 10-20 ppb NO_x, 40-50 ppb ozone.
- NO_x/SO_2 plume downwind of Oildale.
- Two pollutant layers (720 and 1320 m) morning of November 26.

Tracer - Initial transport towards the southeast by northwesterly winds. 23 ppt average over 6 hours as far east as Keene near Tehachapi Pass.
- Tracer transported back towards mid-valley by drainage flows. SF_6 detected south of Bakersfield throughout the night.
- Tracer also transported to west side of valley. 89 ppt at 0400 at Buttonwillow, average of 77 ppt between 0300 and 0700.

- Westerly winds aloft throughout night possibly leading to loss of more than half of the tracer.
- On day after release, SF_6 spread uniformly over southern valley.

Test 4 - Valley Acres, November 29, 1978 (1200-1700 PST)

Meteorology
- Weak synoptic scale flow, stable air mass over California.
- Temperatures aloft (850 mb) 2°C above 5-year average.
- Light transport winds, from the east during afternoon, switching to nighttime drainage (westerly) and northwesterly by 1000 the following day.

Air Quality
- Moderately high pollutant levels. Ozone peak 0.07 pppm at Fountain Springs.
- Limited mixing led to high pollutant levels near significant sources (SO_2 500 ppb at Bakersfield, NO_x 120 ppb).
- 77 ppb SO_2, 57 ppb NO_x north of McKittrick.

Tracer
- Initial transport north towards Buttonwillow (490 ppt) moving 1.5-2 mph.
- Predominant easterly winds during release led to transport towards Fellows. Horizontal dispersion corresponded to stability class A or B.
- Nighttime drainage winds led to transport of both northern plume (near Buttonwillow) and southern plume (near Fellows) back across center of valley.
- 43 ppt detected at Mettler (0900); 47 ppt Greenfield (1000); 24 ppt Lamont (1000) on morning after release.
- 28 ppt at Woody (0300 to 1200 average); also at Wasco, Delano and Richgrove.
- More than half of SF_6 released probably remained within the valley by day following release.

- Continued easterly transport on second day after release. 12 ± 2 ppt detected as far east as Caliente midafternoon, 13 +/- 2 ppt detected east east of Caliente late afternoon.

Test 5 - Lost Hills, December 8, 1978 (1400-2030 PST)

Meteorology
- Rapidly stabilizing atmosphere after passage of frontal system.
- East to northeast winds at release site switching to westerly by 1800.
- Westerly drainage very shallow.

Air Quality
- Generally low pollutant concentrations in aftermath of frontal system.
- Light NO_x and SO_2 plumes over oilfields.
- 84 ppb NO_x maximum near McKittrick.
- 27 ppb SO_2 maximum near Bakersfield.

Tracer
- Tracer first detected northwest of Lost Hills.
- Transport speed ~5 mph.
- Detected as far west as Cholame (Cottonwood and Polonio Passes).
- Mass balance
  - 25-30 ppt, 20 miles x 30 miles x 3000 ft = 75 percent of release.
- Shallow drainage winds near end of release led to concentrated plume transported to Buttonwillow and a return of tracer initially transported northwest.
- By 0400, 20 ppt near southern sites of Mettler and Old River.
- At same time similar concentrations near Wasco and Richgrove.
- Southern plume -- SF_6 progressed farther east on day after release; 55 ppt, Lamont (1000); 38 ppt, Greenfield (1000); 38 ppt, Edison (1300) and 26 ppt, Mettler (1400).
- By late afternoon, well-mixed southeast of Bakersfield at 15 ppt ~1/3 of tracer release.

- Northern plume -- 58 ppt at Wasco (0800); 97 ppt, Delano (0600) as much or more than amount of tracer southeast of Bakersfield.
- Second day after release, 5-10 ppt over entire southwest end of valley.

Test 6 - Lost Hills, February 6-7, 1979 (2000-0800 PST)

Meteorology - Generally stable conditions. Light southwesterly drainage winds at release site during night.

Tracer
- Tracer transported by nighttime drainage winds to valley center; Alpaugh (2300) and (0400-0800), 47 ppt maximum.
- 167 ppt at Corcoran (0800).
- 20 ppt at Hanford (0800-1300) ~4 mph transport time.
- Tracer transported back towards southern end of valley during day after release.
- Syringe contamination limited samples.
- On second day after release, SF_6 detected both near Corcoran and east of Bakersfield.

Test 7 - Lost Hills - March 6-7, 1979 (2030-0800 PST)

Meteorology - Generally stable, stagnant conditions. Light southwest winds at release site during night.

Tracer
- First detected in Alpaugh (0300) ~3 mph transport 700 ppt maximum and 410 ppt average between 0400-1000 at Alpaugh.
- Wasco first detected SF_6 at 0700 PST.
- On day after release, generally southerly transport 52 ppt at Old River between 1000-1100.
- 360 ppt Lost Hills (1300 PST)
- 160 ppt near Buttonwillow (1630 PST), 17 ppt average (1600-0000 PST).
- On second day after release, tracer was well mixed 20 $\pm$ 4 ppt over entire center of the valley.

- Transport back northwards during nighttime drainage winds. Maximum of 31 ppt at Hanford at 0300 PST (March 9).
- Concentrations on March 9 about half that of previous day.
- Low but non-zero concentrations detected throughout the valley (Bakersfield to Corcoran) on March 10, 1979.
- Mean residence time

Day	Amount Remaining
0	100%
1-1/2 - 2	95
2-1/2 - 3	50

Mean residence time or characteristic exchange rate about 4 days based on 50 percent removal estimate 2-1/2-3 days after release.

5. Conclusions

1. The November-December 1978 field program was characterized by below normal average 850 mb temperatures but with a few periods of above normal temperatures. Maximum pollutant concentrations in the valley were slightly less than those observed in the November-December period of 1977 and 1979.
2. The November-December period included stable periods of potential pollutant accumulation of 4-11 days duration. These periods were interrupted by trough passages and moderate winds which serve to flush out the valley. Visibilities respond quickly to these changes and provide a good indicator of potential stagnation periods.
3. At night drainage air from both sides of the valley tends to flow to the center of the valley, creating an apparent convergence zone. During the late forenoon, the slopes become heated sufficiently to cause upslope winds and northwesterly flow throughout the southern end of the valley. Pollutants may be transported out of the valley during this afternoon flow. These wind patterns were remarkably consistent throughout the stable periods. In spite of the low wind velocities observed, transport of the tracer was observed over a wide area.
4. Mixing layer depths were observed to range between 500 and 800 m (above ground level) during the stable portions of the November-December program.
5. Maximum ozone concentrations throughout the valley did not exceed .08 ppm during the November-December field program. Ozone concentrations at night in the valley often drop below .01 ppm in spite of the low, concurrent values of NO_x. It is suggested that the winter background levels may be low or that another depletion mechanism may exist.
6. CO and NO_x concentrations show wide variability in the valley, reflecting the urban influences on pollutants. Timing of the peaks indicates a primary mobile source. Peak concentrations at Reedley were a factor of four or more less than those measured at Fresno-Olive, indicating the rapid dilution into rural areas.

7. Peak SO_2 concentrations were found to be related to specific source areas such as Oildale. Timing of the observed peaks suggested wind transport relationships with the known source areas.

8. Sources of carbon, ammonium nitrate, ammonium sulfate and fugitive emissions of dust accounted for most of the measured, total particle mass.

9. The first two tracer releases (Chowchilla and Fresno) exhibited similar characteristics. During the late afternoon and early evening the tracer material drifted slowly northward. A southerly drift occurred during the forenoon of the following day. Most of the tracer was contained within a radius of 70 miles after 24 hours. Upward mixing (to 500-800 m) diluted the tracer material on the day after release.

10. The following two releases (Bakersfield and Valley Acres) were similar in that the tracer was carried initially upslope by the afternoon slope heating. In both cases, however, the evening drainage flow commenced before the tracer material had exited from the valley. The tracer was then carried back downslope and across the valley by the morning of the next day. The tracer material was then mixed upward and spread throughout the southern part of the valley by the afternoon northwesterly flow. Most of the material was believed to have been carried out of the valley by the evening of the second day.

11. The Lost Hills release showed similar characteristics but the material ultimately divided into two branches. On the morning following the release, tracer material was found to the east and southeast of the release site. Thereafter, it was carried upslope during the afternoon.

12. Tracer material released on either side of the convergence zone appeared on the other side during the morning after release. In some cases, the cross-valley transport appeared to occur in spite of the convergence zone. In any event, by late forenoon, the convergence zone generally disappears and mixing occurs throughout the southern end of the valley.

13. During the February and March tests from Lost Hills, tracer behavior was similar to the November-December period. The tracer tended to flow toward the center of the valley during the night and toward the south and upslope during the daytime. Flows were weaker than in November-December as a result of greater stability. As a result, the ability of the valley to ventilate itself was reduced. It was estimated that about half of the tracer was removed from the valley within 60 hours after the release.