PLUME SIMULATION GAS TRACER STUDIES DURING WINTER, SPRING, AND SUMMER, 1976, IN UPPER HAT CREEK VALLEY

VOLUME I - TECHNICAL REPORT

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BY

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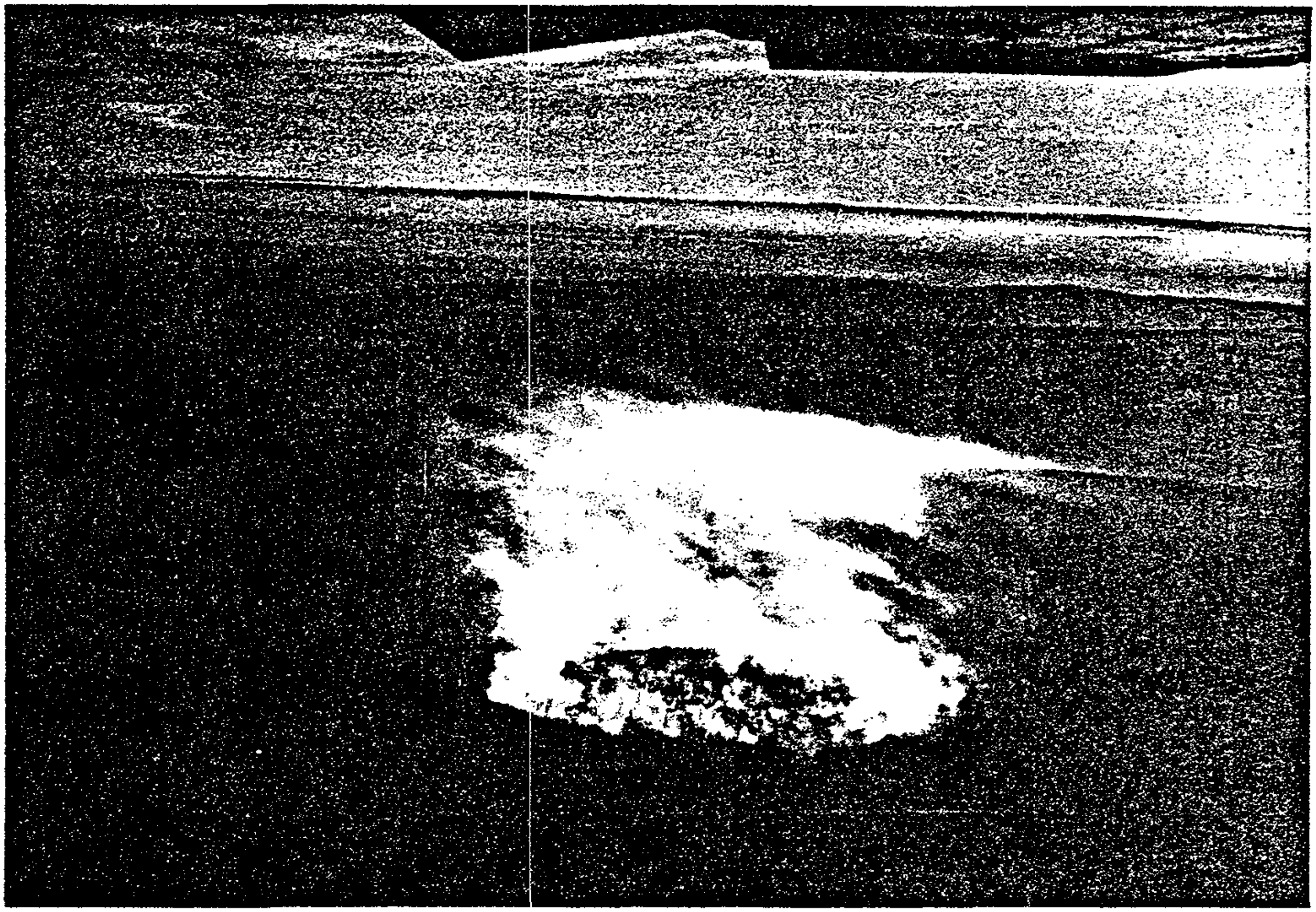

FRONTISPIECE - An oilfog plume drifts northeastward from the release point over the proposed upper plant site at Hat Creek, B. C. This photo shows the beginning of tracer Test 14 at 0555 PST, August 11, 1976. The fanning plume was tracked aloft for more than 80 km with no measurable surface impact. Aerial tracer tests such as these assist in visualizing airflow patterns and in calibrating diffusion models used to determine the air quality impact of proposed power plants.

ABSTRACT

Three gas tracer studies have been conducted during 1976 in the Upper Hat Creek Valley for British Columbia Hydro and Power Authority. The studies, performed by North American Weather Consultants (NAWC), were designed to evaluate the potential impact of sulfur dioxide emissions from the proposed Hat Creek Power Project.

A total of 14 tracer releases was made during the winter, spring, and summer seasons simulating the SO_2 emission from a 2000 MW (net) fossil fuel power plant located either in the valley (lower site) or at a higher elevation on the eastern ridge (upper site).

The results of the field studies, using stack emission parameters as specified for these tests, show the following:

1. The lower site in Hat Creek Valley has been found to be unacceptable with stack heights as high as 366 m.

2. In order to locate the proposed fossil fuel plant in Upper Hat Creek Valley, the site must be at an elevation comparable to that used for the upper site with stack height significantly greater than 183 m.

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1. INTRODUCTION

During 1976, North American Weather Consultants (NAWC) received Purchase Orders #643-696 and #648-195 from British Columbia Hydro and Power Authority to perform gas tracer studies in support of plant site evaluation efforts in Upper Hat Creek. The purpose of the studies, as stated in the Original Terms of Reference, dated December 19, 1975, was:

> This field study will investigate the dispersive quality of the lower atmosphere, and plume trajectories during the winter season. The study will also further investigate meteorological phenomena observed during the first two field studies.

The area examined was the Upper Hat Creek Valley, located about 80 km west of Kamloops, British Columbia. The Hat Creek region is located on a plateau characterized by numerous low mountain and valley chains. Within a few kilometers two major rivers, the Thompson and the Fraser, determine the topography which strongly influences the climatology of the region. The Upper Hat Creek Valley itself is 5-10 km wide with sides rising steeply to 1400-1600 m MSL. The ground cover is primarily 5-15 m tall conifers which have been partially logged with extensive clearing for cattle ranching on the valley floor.

Two prospective power plant sites have been examined. The first is located near the bottom of the Upper Hat Creek Valley at an elevation of approximately 950 m MSL as shown in Figure 1-1. The second site is on the east side of the valley at an approximate elevation of 1350 m MSL.

Three gas tracer studies were conducted during 1976. The first was a winter study and carried out during the period February 16-23, 1976. Tracer gas and visible oil-fog were released at

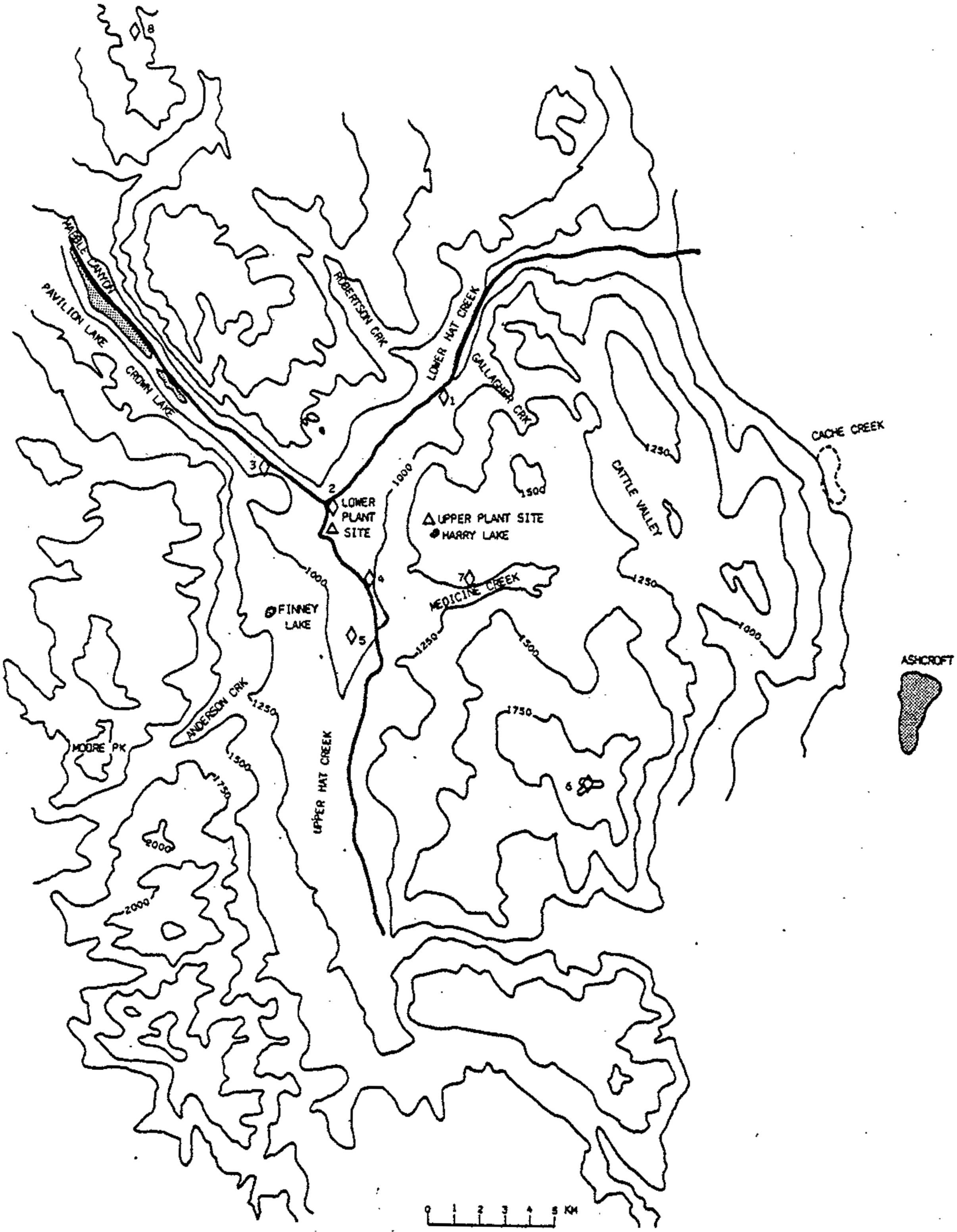


Figure 1-1 General Research Area. Diamonds indicate locations of B. C. Hydro weather stations.

the two prospective power plant sites in Upper Hat Creek Valley under both stable, low wind speed conditions, and more windy, neutral flows. The study was terminated earlier than planned due to unsuitable meteorological conditions. However, some of the results from the study indicated that a second short study would be advisable to more extensively examine stable up-valley flow at the lower valley site.

The second field program was a spring gas tracer study and was conducted without any oil-fog during the period March 22-26, 1976. The weather was again variable, and the releases were performed under windy, neutral conditions at both the lower and upper sites.

The third field program was a summer study conducted between July 31 and August 10, 1976. A total of eight tracer releases was made from the upper site. Atmospheric conditions included stable air mass with low wind speed, light winds with unstable afternoon lapse rate, and neutral stability with moderate wind speeds. One release was carried out from the lower site under looping plume conditions.

This report describes the research methods used in the studies and provides conclusions concerning the feasibility of building a fossil-fuel power plant at either location with regards to air quality impact. The evaluation was based upon the B. C. Hydro Gas Tracer Meteorological Study Criteria for the Proposed Hat Creek Thermal Power Plant which are listed in Table 1-1.

During the course of the field study, the stack heights were adjusted based upon the preliminary results from the field measurements. These adjustments applied to both the valley site and the upper site.

The results presented in this report concern ambient SO_2 levels only, based upon coal with 0.5% sulfur content. It should

Table 1-1 B. C. Hydro gas tracer meteorological study criteria for proposed Hat Creek Thermal Power Plant.

	Valley Site	Upper Site
Stack Height	183 m (adjusted to 305 m based on preliminary field measurements from winter study)	183 m (adjusted from 152 m to 183 m on the basis of field measurements. Experimentally adjusted to 366 m for Test 14).
Stack Gas Temperature	394 K	394 K
Stack Gas Velocity	18.3 m/s	24.4 m/s
*Source Strength SO_2 (based on four 500 MW units)	4204 g/s	4204 g/s

* SO_2 emission rate is based on a coal sulfur content of 0.5%. The emission rate will vary depending on the sulfur content of the coal as fired.

be noted that the results are applicable to coal with different sulfur contents as well as to other gaseous (non-reactive) and particulate emissions by scaling the impact levels in this report to the appropriate new source strengths.

The supporting field data are presented in a separate volume; Volume II - Field Data.

2. SUMMARY AND CONCLUSIONS

Three gas tracer field programs were conducted during 1976 by North American Weather Consultants for British Columbia Hydro and Power Authority to investigate plume dispersion patterns at two proposed power plant sites in the Hat Creek Valley. The winter program, conducted between February 16 and 23, 1976, consisted of three tracer releases. Two releases were made during the spring project between March 22 and 26, 1976. A total of nine tracer tests were carried out during the summer program between July 31 and August 10. These tracer tests were accompanied by extensive meteorological measurements of winds aloft and at the surface, horizontal (constant volume) flow trajectories, vertical temperature profiles, and aircraft turbulence measurements.

The tracer materials, sulfur hexafluoride (SF_6) and oil-fog, were released by aircraft at the calculated effective stack height. SF_6 was measured both at the surface and aloft. Oil-fog was used for quantitative aerial plume tracking and flow visualization.

The gas tracer programs have provided quantitative plume impact evaluations from both of the proposed sites under various meteorological conditions. The critical dispersion regimes of stable plume entrainment within the valley circulation with subsequent fumigation and low wind speed looping were experienced at both sites.

The results of each test are summarized below, with SO_2 concentrations representing equivalent impact from 2000 MW generating capacity. These concentration values have been referenced to both ambient temperatures and pressures at the tracer release altitude and to the "normal temperature and pressure" (NTP) values (i.e., 20°C and 760 mm Hg as specified by the Province of British Columbia. In this report the latter values are designated by (NTP) and are presented for comparisons with the Three-Hour Sulfur

Dioxide Ambient Air Qulaity Objective of 655 μgm^{-3} (NTP) proposed by B. C. Hydro in their brief to the Mining Inquiry.

- Test 1, Febraury 19, 1976. The plume release was made over the lower site assuming a stack height of 183 m. The air mass was moderately stable and winds light and variable, a condition characteristic of the transition from down-valley to up-valley flow. The plume, embedded in the valley circulation, gradually sank as it was transported slowly south and westward and eventually fumigated along the western side of Upper Hat Creek Valley. The maximum measured one-hour surface concentration was equivalent to 3105 μgm^{-3} (NTP), the maximum estimated three-hour concentration was about 1800 μgm^{-3} (NTP) for a continuous release.

- Test 2, February 20, 1976. This tracer release at the lower site was carried out under near neutral conditions at plume altitude with a stable layer below. Winds were moderately strong from the south-southwest. A stack height of 305 m was assumed in an attempt to place the plume above the valley circulation. The plume moved down Hat Creek with the gradient flow, and exhibited terrain channeling. Ground level impact was light with a maximum equivalent one-hour concentration of 243 μgm^{-3} (NTP). Maximum three-hour concentrations are estimated to have been 200 μgm^{-3} (NTP). The low concentrations found during this test are attributed mainly to favorable dispersion conditions rather than the increased stack height.

- Test 3, February 21, 1976. This test was conducted at the upper plant site with an assumed stack height of 152 m. Dispersion conditions were very good with fresh southerly winds and slightly stable lapse rates.

This plume dispersed rapidly and showed little indication of terrain channeling. As a result, the maximum measured one-hour surface concentration was limited to 108 μgm^{-3} (NTP). The maximum three-hour concentration is estimated to have been about 100 μgm^{-3} (NTP).

• Test 4, March 25, 1976. The plume release was made over the lower plant site, assuming a 305 m stack, in a well-mixed atmosphere with neutral stability and moderate westerly winds.

The plume was transported towards the ground sampling network on the elevated terrain to the east of the site. The constant volume balloon data revealed localized circulation patterns with downdrafts which brought some of the balloons to the ground within 4-10 km of the site.

High ground concentration values were found over the sampling network, as would be expected with the observed downdrafts. However, the maximum concentration values were one to two orders of magnitude higher than observed during previous tests and were therefore suspect of contamination. After discarding these extreme values, the maximum equivalent one-hour concentration appears to be 1085 μgm^{-3} (NTP). It is estimated that the maximum three-hour concentration for a continuous release may have been about 465 μgm^{-3} (NTP).

• Test 5, March 26, 1976. The plume release simulated the upper plant site with a 152 m stack. However, in view of the peculiar circulation patterns observed during Test 4, the actual release site was moved 8 km south in order to repeat plume impact on the Trachyte Hills from a higher release point. The atmosphere was again well mixed with neutral stability but the wind increased to strong south-southwesterly flow by the time of the release. No useful quantitative tracer data were obtained from this flight because of suspected contamination of the sampling bags.

• Test 6, July 31, 1976. This early morning test was conducted at the upper plant site assuming a stack height of 183 m. Meteorological conditions were characterized by light to moderate southerly winds and slightly stable lapse rates. A malfunction resulted in a 90% reduction in the source strength of SF_6 during the release, raising the detectable limit for this particular test to 307 μgm^{-3} (NTP).

The plume moved northward and showed little indication of interaction with the terrain or of surface impact within 35 km of the plant. It is concluded that the lack of downward transport resulted in one-hour concentrations of no more than the detectable limit of 307 μgm^{-3} (NTP). Maximum three-hour concentrations are estimated to have been about 75 μgm^{-3} (NTP), well below the detectable limit.

- Test 7, August 1, 1976. This early morning tracer release was made over the upper plant site, assuming a stack height of 183 m. The plume was released near the top of a weak surface-based inversion, and was transported initially towards the northwest. The stable-appearing plume approached the elevated terrain to the northeast of Marble Canyon, causing moderate surface impact. The plume then drifted slowly to the west and southwest, passing over Marble Canyon and was last visible over the hills west of Crown Lake. Measurable surface impact was experienced only on a small area of the plateau northeast of Marble Canyon, where a maximum one-hour concentration of 330 μgm^{-3} (NTP) was recorded. The distribution of surface concentrations suggests that this test represents a case of a lofted plume impact on elevated terrain. Surface concentrations might have been higher had stronger insolation (and therefore greater vertical mixing) been present. In view of the observed shifting plume trajectory, maximum three-hour concentrations are estimated to have been 140 μgm^{-3} (NTP).

- Test 8, August 5, 1976. This early morning test simulated emissions from a 183 m stack at the upper plant site. The atmosphere was neutral at plume height, with a shallow surface-based inversion below. Winds were from the northwest at moderate speeds. The plume was transported to the southeast and split into two sections over Medicine Creek. One branch continued over upper Medicine Creek, while the other branch moved to the east and then southeast as it followed Cornwall Creek. No surface impact was detected at any of the sampler sites, probably due to a combination of favorable dispersion conditions. The maximum three-hour concentration from a continuous source is estimated to have been less than 50 μgm^{-3} (NTP).

- Test 9, August 6, 1976. This early afternoon test was conducted at the lower plant site assuming a stack height raised to 366 m. The atmosphere was neutral at plume height with a shallow superadiabatic layer at the surface. The wind was very light. The plume behavior was marked by extensive vertical transport in the well-organized convection cells. As a result, surface impact was varied and widespread across the upper valley. The maximum one-hour equivalent SO_2 concentration was 1068 μgm^{-3} (NTP) 2.4 km southwest of the lower plant site. The estimated maximum three-hour concentration, based on a continuous source, was 525 μgm^{-3} (NTP).

- Test 10, August 7, 1976. Test 10 was an early morning test carried out at the upper plant site assuming a stack height of 183 m. Except for a shallow surface inversion, the air mass was near neutral with light northerly winds. Weather conditions deteriorated during the test and the tracer release was cancelled after 40 minutes, when the lowering visibility made successful low altitude flying unlikely. The abbreviated plume was visually noted to pass over one sampler, but no measurable impact was recorded over the sampling network. It is presumed that the combination of low wind speeds, surface stability, and cloudiness suppressed vertical mixing, resulting in observed one-hour and estimated maximum three-hour concentrations of less than the detectable limit of about 30 μgm^{-3} (NTP).

- Test 11, August 9, 1976. This early morning test was conducted at the upper plant site assuming a stack height of 183 m. Winds were strong (7-8 m/s) and the air mass, neutral. The plume was transported toward the southeast and was tracked down Cornwall Creek to near the Ashcroft airstrip. The data indicate that the strong winds and neutral atmosphere caused very rapid dispersion near the surface, resulting in maximum one-hour surface concentrations of 175 μgm^{-3} (NTP). It is estimated that the maximum three-hour concentration did not exceed 50 μgm^{-3} (NTP).

• Test 12, August 10, 1976. Test 12 was an early morning test using a simulated 183 m stack at the upper plant site. The plume height stability was neutral, but surface inversions were observed at both valley and hillside locations. Initially, the plume drifted slowly to the south (up-valley) for about 90 minutes, extending as far as Oregon Jack Creek. After that, the plume began to move westward as it was entrained in a cross-valley circulation caused by solar heating of the east-facing slopes. Through the test the plume layer was observed to sink in response to the effect of the differential heating in the valley. The plume fumigated on the western slopes of the valley, dispersing up the slopes. The maximum one-hour equivalent SO_2 concentration was recorded during the fumigation period and had a value of 646 μgm^{-3} (NTP). A one-minute grab sample at that sampler site had a concentration of more than 8600 μgm^{-3} (NTP). The great range in one-minute to one-hour average concentrations is typical of the short-lived fumigation process. This test demonstrated the depth and transport capacity of the valley circulation. The maximum estimated three-hour concentration was about 527 μgm^{-3} (NTP) for a continuously operating source.

• Test 13, August 10, 1976. This test was conducted at the upper plant site near noon. The tracer release simulated emissions from a 183 m stack. The atmosphere was neutral and winds were very light. As in Test 9, plume transport was greatly influenced by well-organized convection. During the early phase of the test, the tracer release aircraft encountered extreme down-drafts and held altitude only by the use of full power. Organized, but less severe, up- and down-drafts were encountered throughout the remainder of the test. Although surface impact was widespread, the maximum value was found within 1 km of the upper plant site and had a one-hour average equivalent SO_2 concentration of 1216 μgm^{-3} (NTP).

Concentrations in the central Hat Creek Valley were lower, averaging at most 215 μgm^{-3} (NTP) for a one-hour period. The maximum three-hour concentration is estimated to have been about 450 μgm^{-3} (NTP).

- Test 14, August 11, 1976. This early morning test simulated emission from a 366 m stack at the upper plant site. The raised stack height was used to investigate possible entrainment in the valley circulation at this higher level. The air mass was neutral with shallow morning surface inversions and winds were from the southwest at speeds of 3 to 4 m/s. Plume transport was similar to that of Test 6 except that this plume remained at greater heights above the terrain. The plume was tracked for over three hours, during which time it passed over more than 80 km of moderately rough terrain, showing no signs of significant interaction with local circulations. Surface impact was negligible and the maximum three-hour concentration is estimated to have been less than 30 μgm^{-3} (NTP).

- Conclusions. The gas tracer studies at the proposed Hat Creek generating station sites have provided quantitative information of plume dispersion behavior under variety of meteorological regimes.

The lower site has been found to be unacceptable with stack heights high at 366 m, due to the depth of the valley circulation. One-hour concentrations up to 3105 μgm^{-3} (NTP) were found during a winter fumigation episode with a 183 m stack. Estimated maximum three-hour concentrations for that experiment ranged as high as 1800 μgm^{-3} (NTP). During summer, assuming a 366 m stack, one-hour concentrations reached 1068 μgm^{-3} (NTP) during a test conducted under typical convective afternoon conditions. The maximum three-hour concentration for that test is estimated to have been about 525 μgm^{-3} (NTP).

The upper site, with a stack height of 183 m, has also been found to be unsuitable, although dispersion appears to be excellent during periods of moderate winds and neutral stability. In the 183 m configuration, one-hour surface concentrations reached 1216 μgm^{-3} (NTP) during a test conducted under light wind, looping plume conditions. It is estimated that the maximum three-hour concentrations during this test reached 450 μgm^{-3} (NTP). An early morning release, carried out during a period typified by light winds and near neutral lapse rates, resulted in one-hour concentrations of up to 646 μgm^{-3} (NTP), and a maximum estimated three-hour concentration of 527 μgm^{-3} (NTP), after a long period of complex transport.

One test was conducted from the upper site, assuming a stack height of 366 m. Conditions were relatively favorable for entrainment in the valley circulation, yet the plume traveled more than 80 km across moderately rugged ground with no indication of significant interaction with the terrain or surface impact.

In summary, the results of the tracer study show that in order to locate a 2000 MW fossil fuel power plant in the Upper Hat Creek Valley with stack emission parameters as specified by B. C. Hydro (Table 1-1), the site must be at an elevation comparable to that used for the upper site with stack height significantly greater than 183 m.

3. RESEARCH METHOD

The plume simulation gas tracer study conducted in Upper Hat Creek Valley was designed to provide a quantitative evaluation of atmospheric dispersion under various meteorological conditions for each of the two proposed plant sites. The tracer materials used were oil-fog and sulfur hexafluoride (SF_6).

These plume simulation techniques have been used extensively in atmospheric diffusion studies for many years and have been well documented in the literature (e.g., Slade, 1958; Niemeyer and McCormick, 1968; Start et al., 1973; and Dickson, 1974). During recent years, NAWC has refined the oil-fog and SF_6 tracer technique for quantitative dispersion evaluations and flow visualization in the simulation of large elevated emission sources in complex terrain. Results from recent studies that have used this technique (Anderson et al., 1976; Petersen et al., 1976; Hovind et al., 1975; and Spangler et. al., 1976) have shown the manner in which dispersion in rough terrain can be estimated quantitatively.

3.1 Tracer Dissemination

3.1.1 Oil-Fog Dissemination. Aerial oil-fog is generated by an aircraft which can carry a large supply of corvus oil and is capable of providing up to 45 minutes of continuous oil-fog. This fog is produced when oil injected into the exhaust manifold is vaporized. Upon entering the ambient air, the oil vapor condenses rapidly into a plume of dense bluish-white fog of primarily submicron particles. The bluish-white fog remains visible for a few minutes to several hours, depending upon prevailing dispersion conditions. The oil-fog plume allows quantitative concentration measurements using the integrating nephelometer in the NAWC research aircraft (see Section 3.2) as well as qualitative visual and photographic observations of air flow and dispersion patterns.

Aerial oil-fog was generated by the 650 hp Stearman biplane shown in Figure 3.1-1. The oil-fog was released simultaneously with the gas tracer at a calculated effective stack-height level arrived at using the nomograms shown in Figures 3.1-2 (winter) and 3.1-3 (summer). The Stearman released both oil-fog and SF_6 while flying circles of about 130 m radius around a fixed ground reference.

3.1.2 Sulfur-Hexafluoride Dissemination. Except in tests 4 and 5, SF_6 was released simultaneously with the oil-fog from the Stearman biplane. Three gas cylinders, each containing eight kilograms of SF_6, were mounted in the cockpit. These bottles were connected to a two-stage regulator through which the gas was released at a constant rate. The gas was routed from the regulator through a polyethylene tube, exiting at the rear of the fuselage. The SF_6 bottles were weighed prior to and immediately following each release to measure the exact amount released. An emission rate of about 5 g/s was used.

The possibility of an interaction between SF_6 and oil-fog has been explored in earlier studies. For example, the NOAA Air Resources Laboratory has released oil-fog and SF_6 simultaneously on several occasions and has detected no significant interaction (Start et al., op. cit., and Dickson, op. cit.).

3.1.3 Comparison of the Tracer Source to Actual and Model Sources. When considering the size and shape of the tracer source used to simulate the proposed power plant stack effluents, the question arises of how closely does the tracer source resemble the actual effective effluent source. Since the nonbuoyant tracer material must be disseminated at the effective stack height, the point of comparison between the sources is where the plant plume approaches effective stack height. Observations have shown that the shape and size of a plant plume at that point can be highly variable and sensitive to many parameters.

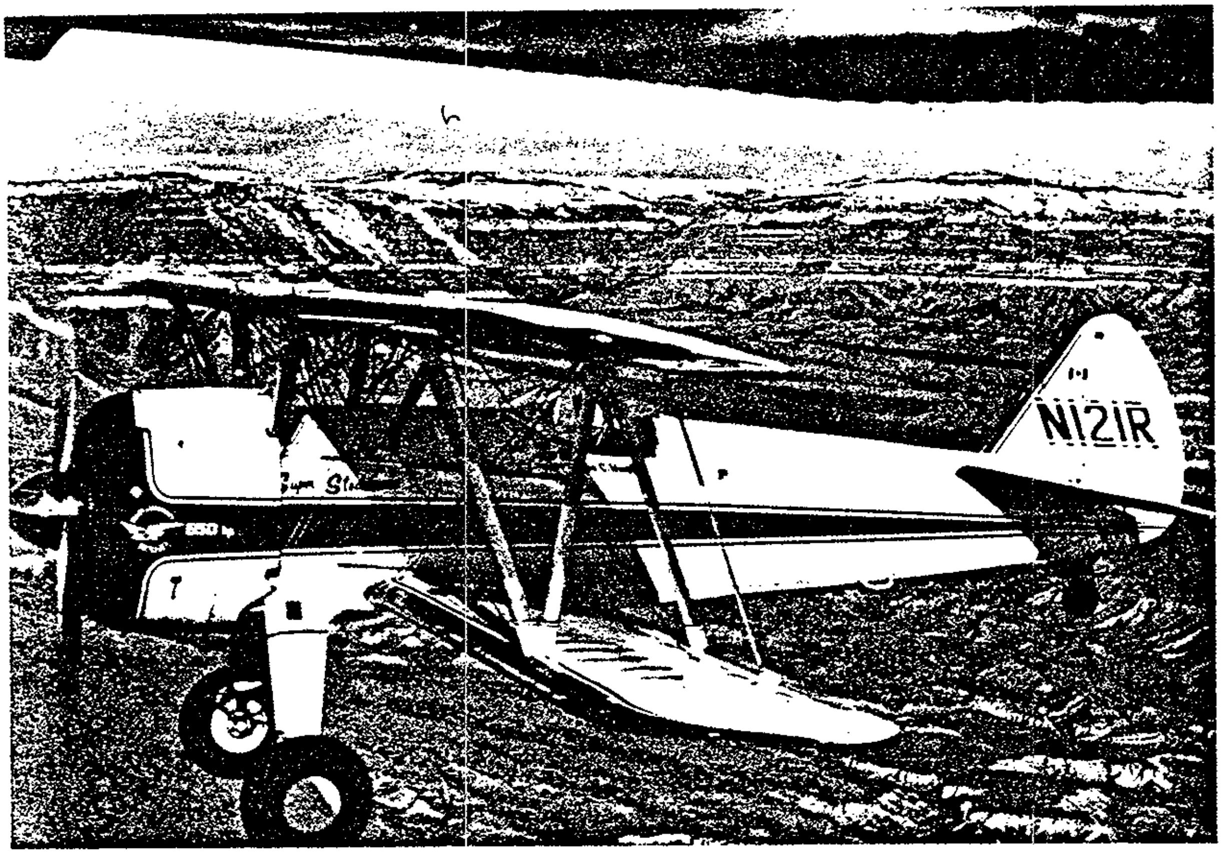


Figure 3.1-1 Stearman aircraft used for aerial oil-fog and SF_6 dissemination.

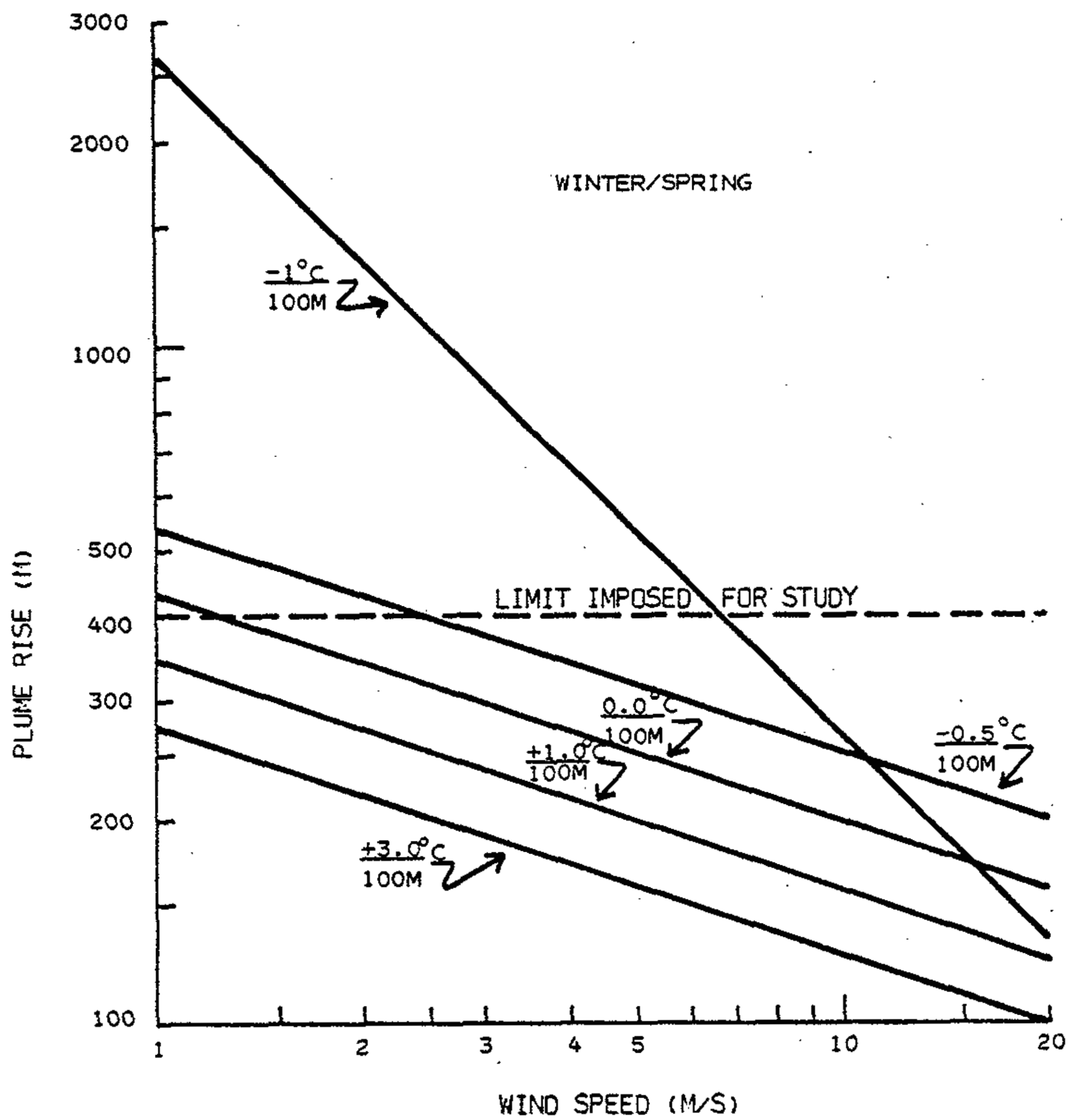


Figure 3.1-2 Nomographs of Briggs plume rise equations used in determining tracer release altitude during the winter and spring programs and during the summer study. A limit of 400 m was placed on plume rise in order to ensure simulation of unfavorable dispersion conditions. Lapse rates per 100 m are shown.

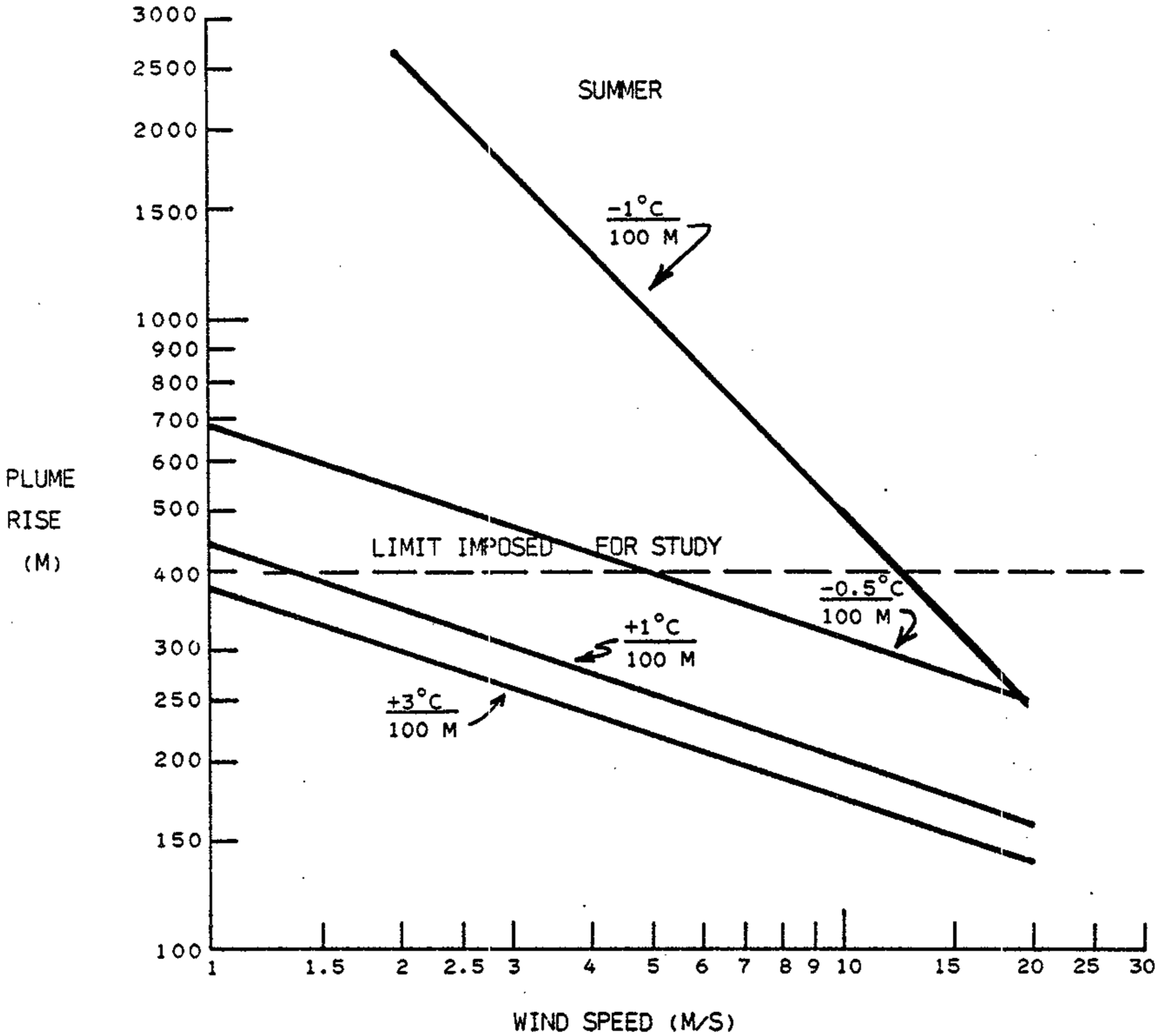


Figure 3.1-2 (Cont'd).

One of the more difficult parameters to assess is the dilution and expansion of the plume by entrainment of the ambient air during plume rise. With a large, hot plume characteristic of a plant the size of the one proposed for Upper Hat Creek, the source area will be large, resulting in significant entrainment during plume rise. In the case of the proposed plant configuration, the dilution through entrainment to reduce the plume temperature to within 2°K of ambient temperature would be approximately 50 to 1. Spangler and Graham (1975) found similar dilution factors while making aerial plume measurements at a coal-fired power plant in Utah. With a stack top diameter for the single Hat Creek stack of 12 m and a dilution ratio of 50 to 1, the projected diameter of the plume after plume rise would be about 85 m, compared with the tracer source diameter of about 260 m. Another aspect of the tracer source to be considered is its depth, which is estimated to be about 30 m. This value is likely to be less than the vertical spread which would be experienced by an actual, buoyant plume.

In comparing the tracer source to a point source, a virtual source distance which varies with the horizontal and vertical dispersion rates must be considered. If it is assumed that the edge of the Gaussian plume is the contour where the concentration is one tenth of the centerline concentration at any distance, then the width and the depth of the Gaussian plume is equal to 4.3 σ_y and 4.3 σ_z, respectively, where σ is the dispersion coefficient. Table 3.1-1 below gives the distance from the point source to where the product of σ_y and σ_z for a Gaussian plume is 422 m^2 (i.e., 4.3 σ_z = 30 m and 4.3 σ_y = 260 m, so σ_y σ_z = 422 m^2) for each Pasquill stability category. These distances have been taken into account where observed tracer plume dilution rates and geometry are compared with published estimates for a Gaussian plume.

Table 3.1-1 Table of virtual source distances needed to account for the depth of the tracer source (Turner, 1970).

Pasquill Category	Virtual Source Distance (km) for $\sigma_y \sigma_z = 422\ m^2$
A	0.11
B	0.15
C	0.23
D	0.38
E	0.54
F	0.92

3.2 Tracer Sampling

3.2.1 Oil-Fog Sampling. The oil-fog generated by the Stearman aircraft was systematically sampled with an MRI Integrating Nephelometer. The nephelometer is part of a comprehensive data system installed in the NAWC research aircraft which is described in Section 3.5. The integrating nephelometer measures the scattering coefficient of light caused by suspended particulate in the air. Photomultiplier tubes measure the difference between ultra-violet light (>4100 angstroms) leaving a light source and the light received after traveling through the air sample. The amount of light deleted by the air sample is related to the mass of suspended particulate. The nephelometer used has been modified with an expanded scale ($0\text{-}1000 \times 10^{-4} m^{-1}$) and an averaging time of 0.4 seconds. In aircraft installations the response time is limited primarily by sample train residence time. Residence time can be accurately determined and appropriate corrections made to normalize measurements of plume location and geometry.

The research aircraft systematically tracked the oil-fog plume during and after release as the cloud was transported with the wind. Passes were made perpendicular to the plume at incremental altitudes until the maximum centerline concentration was encountered. When feasible, up to five passes were made at the altitude of maximum observer oil-fog concentration with three passes 15 m (50 feet) above and three 15 m below. This procedure is in accordance with recent work presented by Brown, et al., (1975). They indicate that singular passes through a plume are insufficient to obtain reliable data and recommend a minimum of five passes to reduce the standard estimate of error below 30%. Crosswind patterns flown at numerous downwind distances allow a determination of relative dispersion rates with distance.

The oil-fog plume, being highly visible, was photographed from a light aircraft flying above the plume. A professional meteorologist took both 35 mm slides and Super 8 mm movies of each plume to document plume movement and general behavior. In addition, the exact position of the plume was periodically noted and these positions were used to determine average wind speeds at plume altitude.

3.2.2 Ground Level SF_6 Sampling. Automatic sequential and singular bag samplers (Figures 3.2-1 and 3.2-2) were deployed during each test by helicopter and truck. The single bag samplers pulsed small amounts of air into a Tedlar bag over a period of time selected on a timer. Sample bags were changed approximately every hour during tests and every three hours for background samples. The automatic sequential samplers similarly used separate pulse pumps to fill six Tedlar bags sequentially at a rate of one each half hour. Both types of samplers were designed and manufactured by Mr. C. R. Scholle at NAWC.

3.2.3 Aerial SF_6 Sampling. For aerial SF_6 sampling, a Jet Ranger Helicopter was equipped with a snorkel-type sampling system illustrated in Figure 3.2-3. The probe, weighted to keep it hanging straight, was a polyethylene tube 30 m long with 6.4 mm inside diameter suspended beneath the helicopter. Research

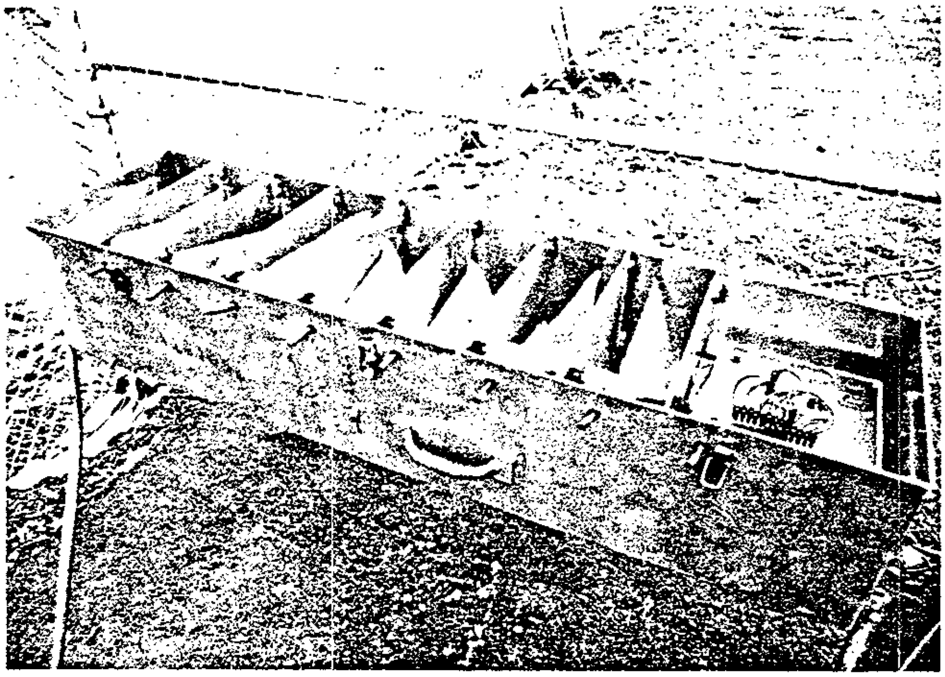


Fig. 3.2-1   Automatic sequential bag sampler.

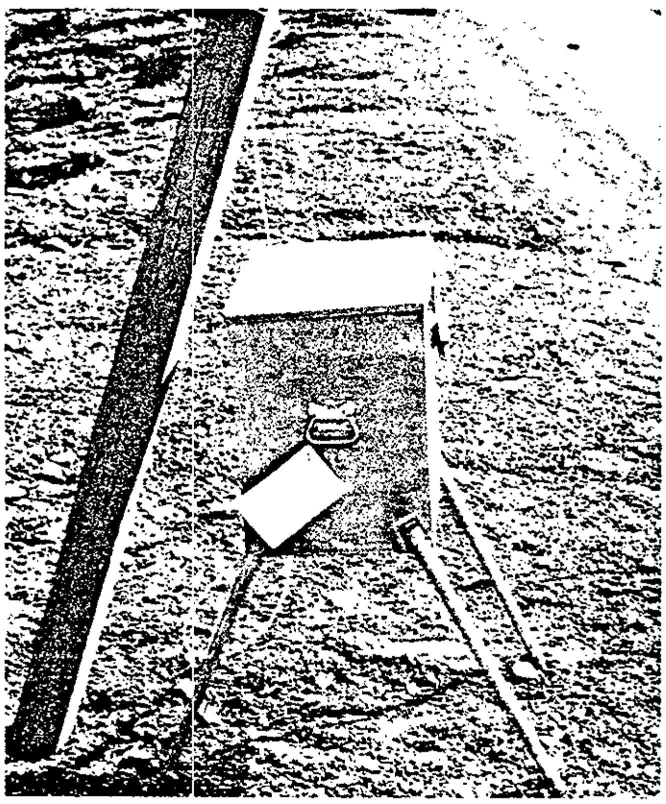


Fig. 3.2-2   Single bag sampler, actuated by mechanical timer.

Fig. 3.2-3 Jet Ranger helicopter with aerial SF_6 sampling apparatus.

(Start, et al., op. cit.) has shown that rotorwash for a somewhat lighter helicopter extends no further than 31 m below rotor height during hover. However, since the Jet Ranger is a heavier machine than that used by Start, samples were taken while moving 5-10 m sec^{-1}, which visual tests showed prevented the downward penetration of the rotorwash to the sample tube inlet.

Ambient air was drawn through the probe by an electric pump at a rate sufficient to insure that sample residence time in the probe was less than two seconds. The pump was powered by a portable generator. Samples were obtained by diverting a small volume of air flowing through the probe into Tedlar sample bags.

3.3 Tracer Analysis

3.3.1 Oil-Fog Analysis. The nephelometer used for sampling the oil-fog tracer measures light scattering coefficient in units of 10^{-4} m^{-1}. The primary task of oil-fog tracer analysis is to convert the measurements of light scattering coefficient to mass concentration which has been developed by Charlson, et al., (1969), and is expressed as:

$$\chi = 0.38\ b_{scat}$$

where:

$$\chi = \text{mass concentration } (gm^{-3})$$
$$b_{scat} = \text{scattering coefficient } (10^{-4}\ m^{-1})$$

This relationship has been confirmed by Eccleston, et al., (1974) who found the range for the conversion factor to be from 0.2 to 0.4.

In order to confirm that the relationship presented above applies to NAWC equipment and sampling methods, comparative concentrations of an oil-fog plume were computed from the nephelometer measurements by an independent method. The NAWC tracer aircraft, equipped with a nephelometer, made measurements of b_{scat} while flying about 100 m behind the oil-fog tracer source (the special sampling maneuver is depicted in Figure 3.3-1). At the same time the size of the oil-fog plume was estimated with reference to the aircraft wing span for use in estimating the oil-fog concentration at the time of sampling. Based on the corvus-oil density of 845 g/ℓ and a vaporization rate of 4.2 ℓ/min, the source strength of oil-fog was computed to be 59 g/s. The diameter of the oil-fog plume at the point of sampling was about 9 m and the Stearman was flying at about 50 m/s. With a volume flow rate of 3180 $m^3 s^{-1}$ and the source strength of 59 g/s, a mass concentration of 1.9×10^{-2} gm^{-3} was computed. The b_{scat} value measured by the nephelometer was 509×10^{-4} m^{-1}. Using Charlson's relationship, the corresponding mass concentration was also 1.9×10^{-2} gm^{-3}. Since the two independent methods yielded the same mass concentration, it is appropriate to use Charlson's relationship to convert the measured values of light scattered coefficient to mass concentration.

Analyses of aerial oil-fog data were performed in order to define plume geometry and dispersion rates during the tests. A system of ground references was generally used during the cross-wind patterns. This allowed accurate spatial reconstruction of the plume thickness, width, and shape, based on measurements made during the sequential passes.

Estimates of the horizontal and vertical dispersion coefficients (σ_y and σ_z) were also made using these data. Estimates of σ_y were obtained by using the plume entry portion of the data from each pass which had a sufficiently high peak to allow good data resolution (usually about 1.0 b_{scat} above background). Only data from the plume entries by the aircraft were used in order to clearly define the plume dimensions. Data from the aircraft plume exits were deleted for this purpose since they require adjustments for the nephelometer sample-train residence time.

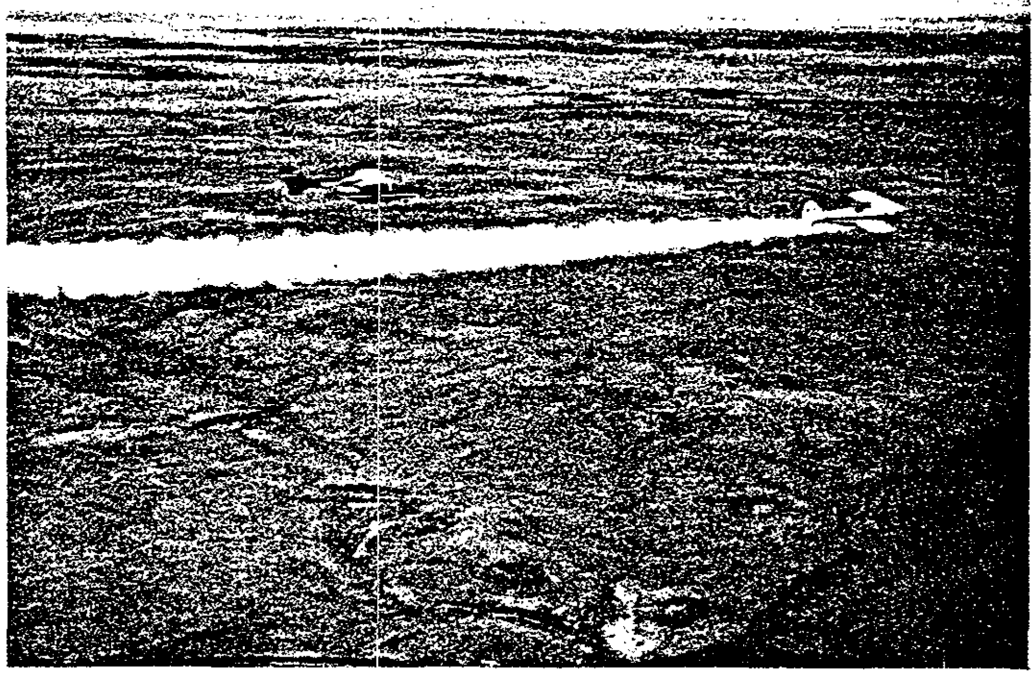


Figure 3.3-1 Aerial measurement of oil-fog source strength to confirm relationship between mass concentration and scattering coefficient.

The estimates of σ_y found in this report represent the mean value for all the qualfying aircraft passes at a particular location. Estimates of σ_z were obtained by averaging the apparent values of σ_z upwards and downwards from the centerline altitude.

The observed σ_z values were at times found to be significantly below the σ_z values given by the Pasquill-Gifford curves (Turner, op. cit.) even after virtual source adjustment. Factors which may have contributed to these differences include subjective judgement in the comparative analysis and the applicability of the Pasquill-Gifford dispersion coefficient to plume dispersion from tall stacks.

The question of what effect the buoyancy differences between the real and simulated (oil-fog) power plant plume may have upon the plume dispersion have also been raised. Certainly the real plume would be deeper, vertically, in its initial bent-over stage than the simulated plume. However, during the subsequent plume transport the observed differences in σ_z values after virtual source adjustments are more likely to be associated with the other factors given above than with the initial differences in plume buoyancy.

Measurements of relative dispersion rates, $\frac{\chi \bar{u}}{Q}$, were made using the observed centerline concentration at a crosswind location. When possible, several passes were made through the plume at centerline altitude and the average maximum centerline concentration was used in the calculation. When only one pass was made at the centerline, the maximum measured value was used. Allowance was made for virtual source distances as outlined in Section 3.1.3.

3.3.2 $\underline{SF_6 \text{ Analysis}}$. All SF_6 samples were collected in two-liter Tedlar bags manufactured by NAWC and each sample was analyzed using an ATC Model 112C portable leak detector (winter, spring) and an AID Model 510 portable gas chromatograph (summer, Figure 3.3-2). Both use gas chromatography and an electron capture detector to measure SF_6 with a sensitivity of one part in one hundred billion. The system uses a carrier gas of 90% argon and 10% methane which serves both as a carrier gas for the sample and as an ionization medium for the detector. The analysis is performed by injecting a known volume of sample into the carrier gas stream by means of a gas sampling valve. The slug of sample is carried into the chromatographic column where it is separated into its individual components. As the constituents of the sample are eliminated from the column, they pass through an electron capture detector which responds to both their relative concentration and electron affinity. The resultant peaks, which appear approximately twenty seconds after sample injection, allow for quantitative measurements of the tracer to be made.

3.3.3 Conversion of Tracer Concentrations to Equivalent SO_2 Concentrations. To relate the results of the tracer to potential ambient study air quality impact, the tracer concentrations and source strengths from the study have been scaled to correspond to the emissions of the proposed power plant. The resulting equivalent SO_2 concentrations are those that would have occurred if the net generating capacity had been 2000 MW. For this study, it was assumed that for each 500 MW generating capacity, the Upper Hat Creek power plant will be emitting 1051 g/s of SO_2, making the total source strength 4204 g/s.

The conversion of measured oil-fog concentrations to equivalent SO_2 concentrations is straightforward. Oil-fog concentrations are expressed in mass-per-volume units so the scaling is done with the equation:

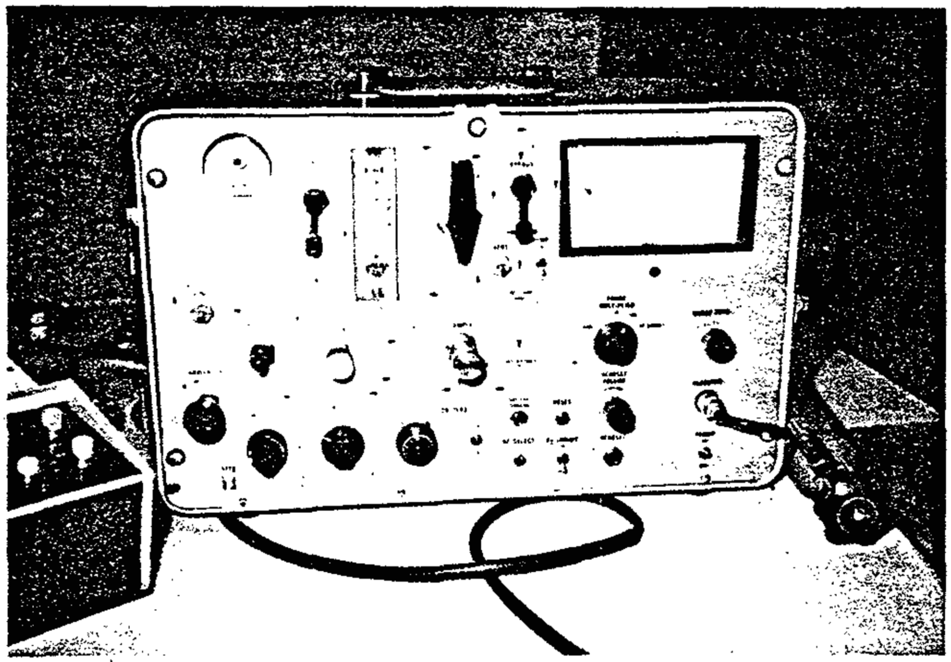


Figure 3.3-2 ATC 112C gas chromatograph used to analyze bag samples for SF_6 concentrations during winter and spring tracer studies. AID 510 instrument, used during the summer program, is similar in appearance.

$$\chi_{SO_2} = \frac{Q_{SO_2}\chi_{OF}}{Q_{OF}} \times 10^6 (\mu gm^{-3})$$

where:

χ_{SO_2} = equivalent SO_2 concentration (gm^{-3})

χ_{OF} = oil-fog concentration (gm^{-3})

Q_{SO_2} = emission rate of SO_2 from the proposed plant (4204 g/s @ 2000 MW)

Q_{OF} = oil-fog source strength (g/s)

SF_6 concentrations are measured by the gas chromatograph in units of parts of SF_6 per billion parts of ambient air so the source strength of the tracer and power plant must be expressed in moles/s rather than g/s for the scaling equation to be used. Also, units conversion factors must be applied if equivalent SO_2 concentrations expressed in mass per volume units are desired. The equation for converting SF_6 concentrations to equivalent SO_2 concentrations is:

$$\chi_{SO_2} = \frac{Q_{SO_2}\chi_{SF_6}}{Q_{SF_6}} \times 10^{-3} (ppm)$$

where:

χ_{SO_2} = equivalent SO_2 concentration (ppm)

χ_{SF_6} = SF_6 concentration (ppb)

Q_{SO_2} = emission rate of SO_2 from the proposed plant (moles/s)

Q_{SF_6} = SF_6 source strength (moles/s)

Unless otherwise stated, all SO_2 concentrations given in this report are referenced to ambient temperature and pressure conditions at plume altitude during the tracer release, and refer to 2000 MW generating capacity. Concentration given as NTP refer to 20°C and 760 mm Hg. Sequential half-hour concentrations from SF_6 samplers were sometimes averaged to obtain one hour concentrations.

3.4 Measurement of Other Parameters

3.4.1 Turbulence. The NAWC tracer aircraft (see Section 3.5) was instrumented with a Universal Indicated Turbulence System used for measuring the average rate of dissipation of turbulence energy (ε) in the inertial subrange. The operation, theory, and evaluation of this instrument have been discussed by MacCready, Niemann, and Myrup (1967). This includes a thorough bibliography on the subject.

In brief, the inertial subrange of eddy sizes is that range of eddies which are small enough to exhibit local isotrophy, but not so small as to lose significant energy through viscous dissipation. Assuming the inertial subrange hypothesis of Kolmogoroff (1941) is correct, the statistical properties of turbulence will depend only on ε, a measure of the continuous flow of energy from larger to smaller eddies. Using this hypothesis, equations relating to the relative diffusion of particles in the inertial subrange have been derived by dimensional analysis (Batcheler, 1950, 1952; MacCready, et al., op. cit.). The equations show that the relative expansion of a pair of particles is directly related to ε. Thus, a comparison of the average values of ε at two different locations should give a quantitative estimate of the difference in diffusion rates at those two sites.

A further consideration is the intermittency of turbulence (I) which may be defined as the ratio between the standard deviation of turbulence values and the average turbulence value or

$$I = \frac{\sigma_\varepsilon}{\varepsilon}$$

Given the same mean rates of turbulence dissipation for two locations, diffusion would proceed more rapidly at that location having a higher intermittency.

Accurate relative turbulence measurements require that the aircraft configuration remain as constant as possible. The measurements are affected, to a greater or lesser degree, by such configuration parameters as airspeed, engine RPM, flap setting, pitch attitude, and probe location. It should be noted that the winter and summer programs were flown with different type aircrafts, respectively, a Cessna 207 and a Cessna 206. Although the analysis of the data does not reveal any obvious inconsistencies, it is possible that the use of slightly different aircraft have introduced some differences in the turbulence data.

Most turbulence data presented in this report come from the oil-fog crosswind patterns, which are, as a matter of method, always flown with the same aircraft configuration. Tracking was done at a speed of about 38 m/s during the winter study and about 42 m/s during summer tests. Other sets of consistent data are available from special turbulence transects made at various altitudes during some of the tests. Again, airspeeds were held constant during these runs though the speed was not always the same as used in tracking oil-fog. Examination of the data indicates that these airspeed changes have little effect as the measurements from either type of pattern generally agree well for a given test.

The turbulence values presented in this report represent the mean of five second interval values which were logged during each crosswind pass or transect. Using airspeed and altitude data provided in the flight log, as well as flight notes, it was possible to insure that no data were taken from periods when the aircraft was turning or changing altitude. Crosswind passes generally lasted about two to three minutes, so each turbulence value represents the average of about 20 to 36 entries. Turbulence transects were usually longer.

3.4.2 Meteorological Measurements. During the field study, several different methods were used to determine temperature lapse rates and winds aloft. The first method was a Contel Minisonde (see Figure 3.4-1) operated by B. C. Hydro personnel from various sites during each study. Minisondes were usually tracked during the ascent by two theodolites which provided accurate winds aloft measurements as well as height information for the sounding. The sonde gives temperature and relative humidity data used for determining stability.

The second measurement system employed during the summer program was a Contel Metrosonde, provided by NAWC, also shown in Figure 3.4-1. This system uses a tethered balloon to carry an instrument package which reports temperature, relative humidity, pressure altitude, wind direction, and wind speed. All channels are radio-telemetered to a ground receiving station for analog recording.

The Metrosonde made serial ascents to determine winds and stability with height. In addition, it was occasionally flown near the effective stack height level to provide a continuous reading of winds. Occasional malfunctions with the Metrosonde prevented its full utilization during the field program.

Vertical temperature profiles were also measured by the NAWC aircraft which is described in Section 3.5. The aircraft was used to make temperature soundings at numerous locations throughout the project area.

The stability classifications assigned to each test were derived from the plume layer lapse rates and classified according to the United States Nuclear Regulatory Commission scheme given in Table 3.4-1 below:

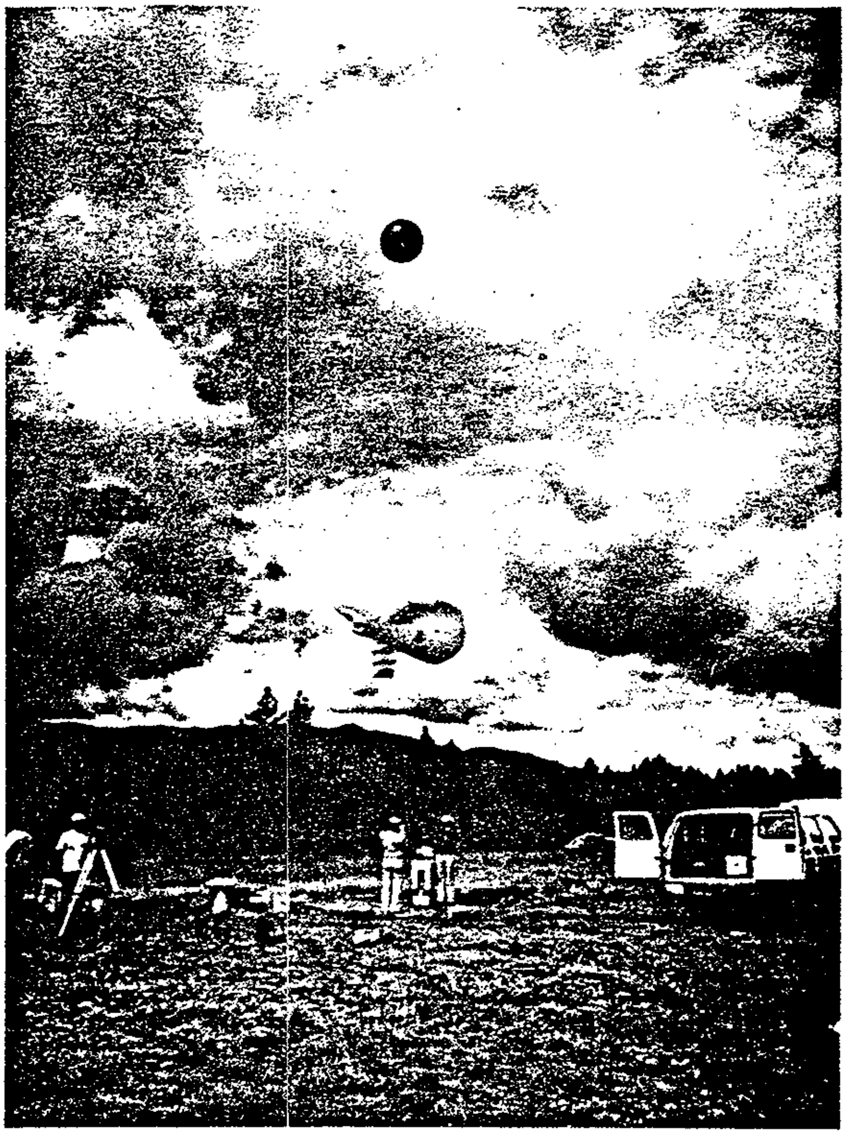


Figure 3.4-1 Balloon launching site at Harry Lake during the summer study. B. C. Hydro and NAWC technicians prepare Metrosonde for ascent. Pilot balloon in background will later be used to carry minisonde temperature sensor aloft.

Figure 3.4.2 Map showing locations of eight mechanical weather stations owned and operated by B. C. Hydro.

Table 3.4-1 Nuclear Regulatory Commission classification of atmospheric stability.

Stability Classification	Pasquill Categories	Temperature Change with Height (°C/100 m)
Extremely Unstable	A	<-1.9
Moderately Unstable	B	-1.9 to -1.7
Slightly Unstable	C	-1.7 to -1.5
Neutral	D	-1.5 to -0.5
Slightly Stable	E	-0.5 to 1.5
Moderately Stable	F	1.5 to 4.0
Extremely Stable	G	> 4.0

Winds aloft were measured during these programs with double- and single-tracked pilot balloons. Constant-volume balloons were used during the winter and spring studies to obtain air-mass trajectory measurements.

Throughout all the studies surface winds were monitored by the B. C. Hydro system of eight remote meteorological stations located within the project area as shown in Figure 3.4-2.

3.5 NAWC Tracer Aircraft

The oil-fog plume tracking, temperature soundings, and turbulence measurements are conducted with the NAWC tracer aircraft. Figure 3.5-1 shows the Cessna T-207, used during the winter study, which is equipped with a Robertson STOL modification for increased safety at slow airspeeds. During the summer program, a similarly equipped Cessna 206 was used. Both aircraft carried the following data acquisition system which is described in Table 3.5-1 below and shown in Figure 3.5-2.

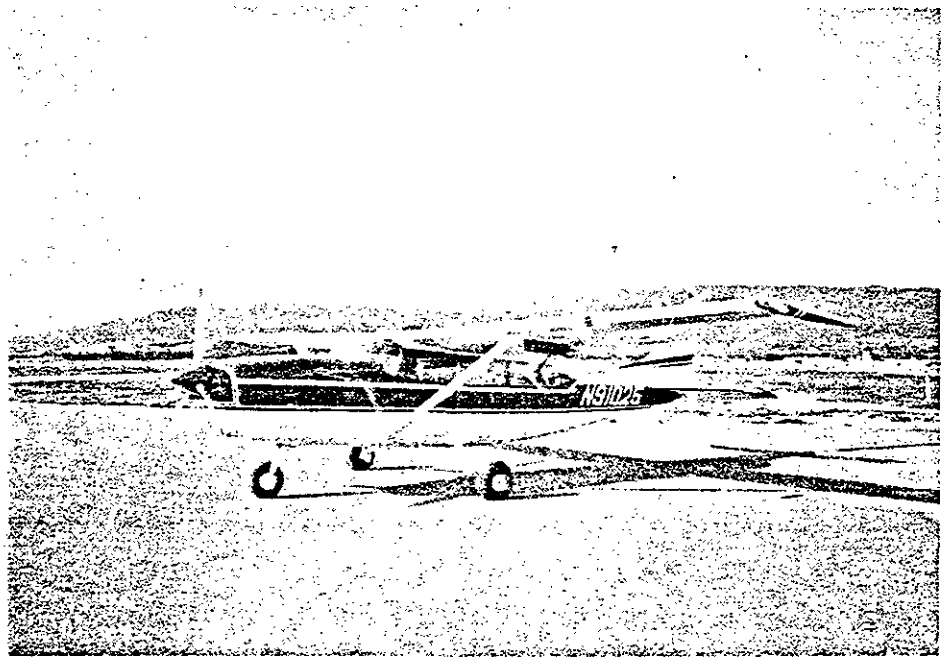


Figure 3.5-1 Cessna 207 used for airborne data acquisition during the winter study. C-206 used during the summer is slightly smaller.

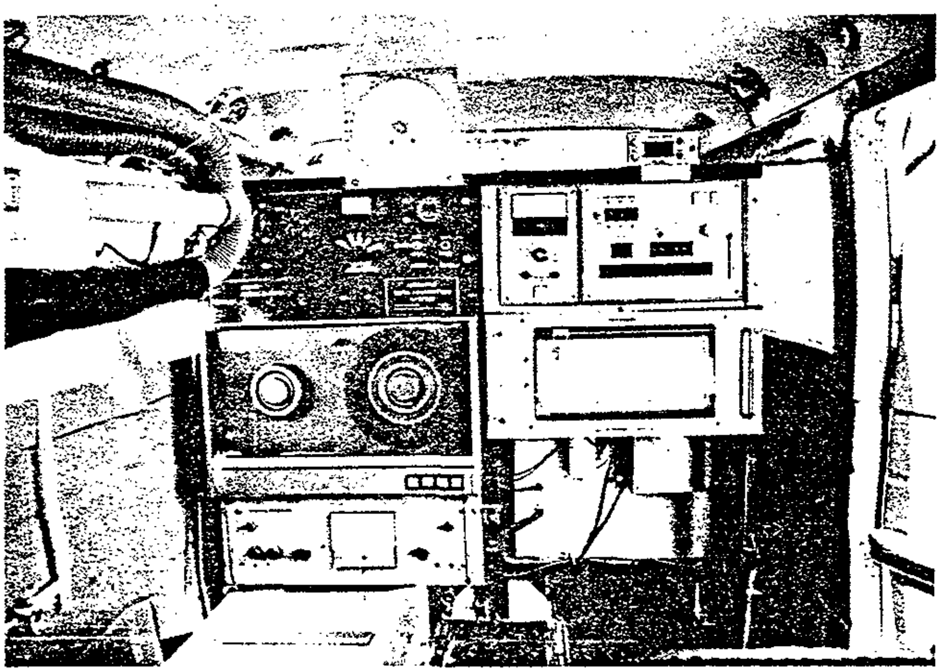


Figure 3.5-2 NAWC airborne data acquisition system installed aboard the NAWC tracer aircraft.

Table 3.5-1 Aircraft data acquisition system.

Meteorological Equipment	Calibration Method
1. MRI Model 1550 Integrating Nephelometer	Absolute calibration is performed using Freon. Repeatability of the calibration is electronically checked before each operation. A special 0-1000 x 10^{-4} m^{-1} scale has been added.
2. MRI Universal Indicated Turbulence System, Model 1120	Both an internal electronic calibration and external check to measure a prescribed system gain are performed before each use.
3. Metrodata M-8 Airborne Meteorological System	Temperature and relative humidity are checked daily against measured values using an aspirated psychrometer. Altitude is checked periodically against the certified aircraft altimeter.

Recording Equipment	Data Recorded
1. Kennedy Model 1600 1/2" Magnetic Tape	All meteorological parameters plus altitude and air speed.
2. Metrodata Model DL-620 interfaced with Kennedy	All meteorological parameters plus altitude and air speed.
3. MRI Analog Chart Recorder	Integrating Nephelometer.

3.6 Quality Control

The execution of plume simulation tracer study requires extensive quality control to minimize operational errors in the measurements and analysis techniques employed. Some of the quality control procedures used in this study are presented in this section.

3.6.1 SF_6 Dissemination, Collection, and Assessments.

SF_6 bottles were carefully weighed on a calibrated balance prior to and immediately following each release. This gave the amount released within an accuracy of about ±50 grams from a total of about 20,000 grams. Dissemination periods were timed with a stopwatch aboard the dissemination aircraft. Amounts and times were documented and registered by project personnel after each operation.

In order to insure that collection data were correct, each sampler was inspected and calibrated with respect to time prior to each program. As a precaution against contamination, a sample was taken from each pump in every sampler before each field study. As a further check, grab samples were taken from the interior of each sampler after field installation. Five to ten background samples were taken prior to each release in order that any fugitive sources of SF_6 might be found. None of these samples taken in the project area showed more than a threshold concentration of the tracer gas (∿0.005 ppb SF_6).

The ATC-112C chromatograph used during the winter and spring study was calibrated with a gas mix supplied and analyzed by the NOAA Air Resources Laboratory in March 1975 (the service was rendered by Mr. C. R. Dickson, Chief, NOAA Air Resources Laboratory, Idaho). Following the winter study, the gas, in its stainless steel container, was returned to the laboratory for reanalysis. A total of 18 samples was taken from the bottle and analyzed on three chromatographic systems. The mean value was 4.27×10^{-10} SF_6, and the standard deviation 6.3×10^{-12}. This value deviates less than 1% from the originally analyzed mix.

The AID-510 chromatograph, used during summer study, was calibrated using gases obtained from Scott-Merrin, Inc. These gases were checked by the NOAA Laboratory in September 1976 and were found to be within 1% of the value specified by the manufacturer. A list of the field calibrations performed during the project is found in Volume II - Field Data. Figure 3.6-1 shows the typical calibration chromatogram.

To demonstrate the reproducibility of the analysis method, 10% of all the bag samples were reanalyzed. The results showed that the method was reproducible with ±5% of the originally analyzed concentration.

3.6.2 Oil-Fog Tracer Generation and Measurement. The oil-fog generation system used was carefully designed and maintained to supply a known, constant source of oil-fog. The oil injection nozzle in the exhaust has been positioned experimentally to insure maximum vaporization of the corvus oil. The corvus oil supply tanks are of a known volume, are completely filled prior to each test, and are completely emptied during each test (one tank can be eliminated from the system for shorter duration oil-fog tests). The pump that supplies the oil to the nozzle operates at a constant flow rate regardless of engine rpm or power setting. Background scattering caused by ambient suspended particulates, although of very small relative magnitude, was frequently measured and later subtracted from the nephelometer measurements made during the tracer flights.

The integrating nephelometer was calibrated according to the manufacturer's specifications and procedures to insure accurate measurements of the oil-fog. An absolute calibration was done in Santa Barbara just prior to the study. Electronic calibration checks were performed daily during the field study.

3.6.3 Accuracy of Wind Measurements. The use of single theodolite systems for making upper wind measurements depends on the reliability of the assumed ascent rate of the balloon. It has been determined that the temperature lapse rate may have a definite, and sometimes adverse, effect on the ascent rate of meteorological pilot balloons (Boatman, 1974). By utilizing a double theodolite tracking system (wherein the two theodolites are separated by a baseline of 300 m or more), it is possible to make very precise measurements of winds aloft that are independent of balloon ascent rate. Reduction of the tracking data was accomplished using the computer techniques. The initial data were smoothed using a method similar to that outlined by Thyer (1970).

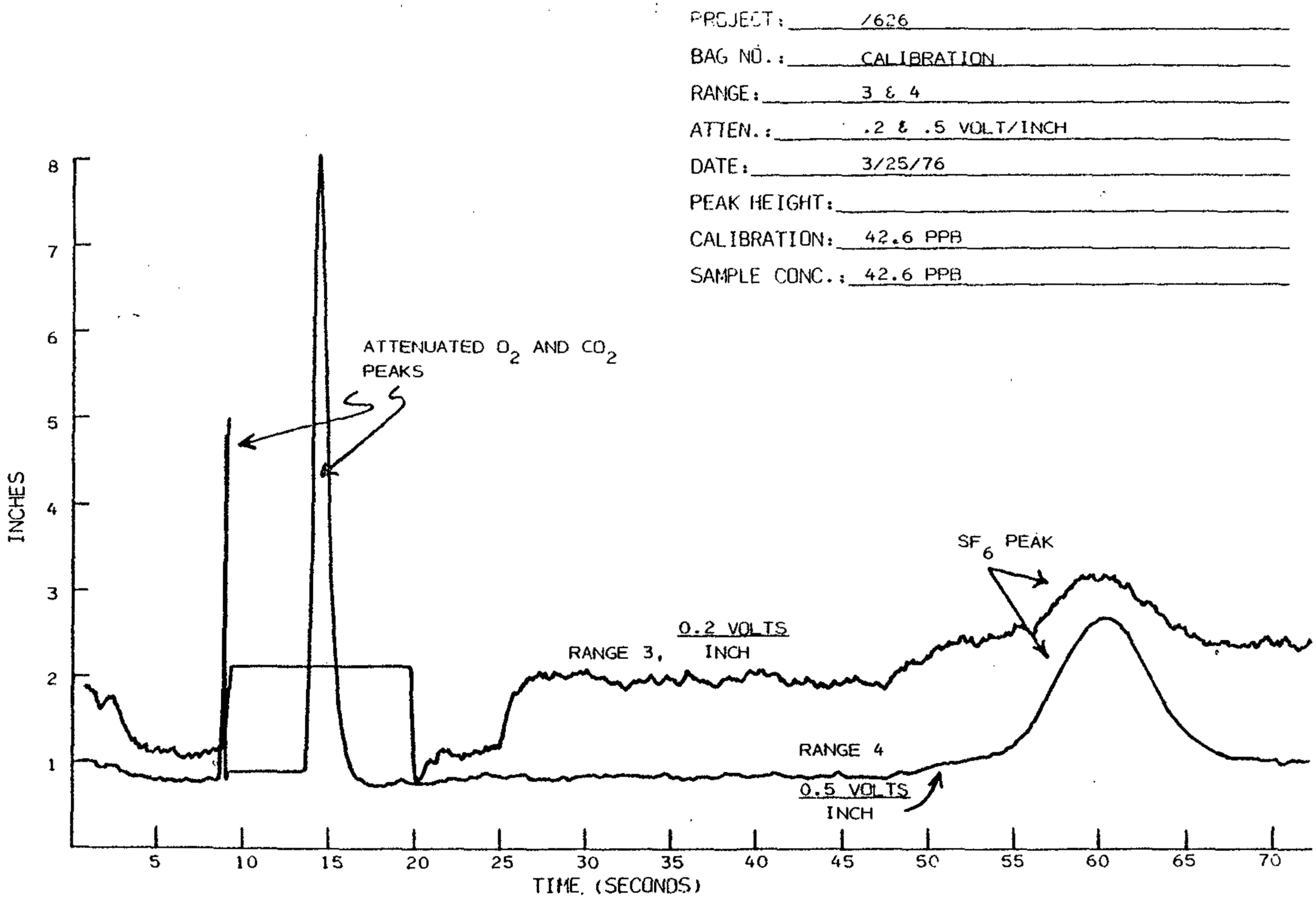


Figure 3.6-1 Typical calibration chromatogram for SF_6.

Research by Butler and Duncan (1968) has shown the double-tracking technique to be accurate within ±1 m/s and ±9° when compared with the sensitive Contraves cinetheodolite system. They also state that errors can be expected to be larger at low wind speeds and greater distances away from the tracking site.

3.6.4 Temperature Soundings. Most temperature sounding data have been processed to correct for observed variances in absolute temperature data between the minisonde system and the M-8 sensor in the tracer aircraft. The M-8 sensor has a high degree of repeatability of measurements and data from this instrument were used to make absolute temperature corrections to the minisonde soundings. Further checks were made by comparing temperature data from the M-8 sensor with data from the Vernon, British Columbia, radiosondes. The results of such comparisons at meaningful altitudes were excellent.

4. DESCRIPTION OF TRACER RELEASES

This chapter presents a detailed description of the fourteen gas tracer releases which were made in the Hat Creek Valley during the 1976 winter, spring, and summer programs.

The tracer releases are referred to as Test 1, Test 2, Test 3, etc., and were conducted on the following dates:

Test 1 - February 19
Test 2 - February 20
Test 3 - February 21
Test 4 - March 25
Test 5 - March 26
Test 6 - July 31
Test 7 - August 1
Test 8 - August 5
Test 9 - August 6
Test 10 - August 7
Test 11 - August 9
Test 12 - August 10
Test 13 - August 10
Test 14 - August 11

The analyses are presented in a basic format which describes Synoptic Setting, Meteorological Parameters, Tracer Dissemination, Visual and Photographic Observations, Aerial Oil-Fog Measurements (except Tests 4 and 5), Aerial SF_6 Measurements, Surface SF_6 Measurements, Turbulence Measurements, and Summary for each test.

4.1 Test Number One, January 19, 1976

This test was conducted from the lower plant site. The meteorological conditions were favorable for examining the behavior of a stable plume and fumigation under very light wind conditions. All SO_2 concentrations reported are calculated per 2000 MW.

4.1.1 Synoptic Setting for Test 1. The surface and 500-mb charts for 1200 Z (0400 PST) are presented in Figure 4.1-1. The surface analysis shows a weak high pressure center of 1013 mb over the project area, while a surface low was developing over the Great Basin. Some slight ridging over the area can be noted on the 700-mb chart as a split in the upper level flow placed the jet

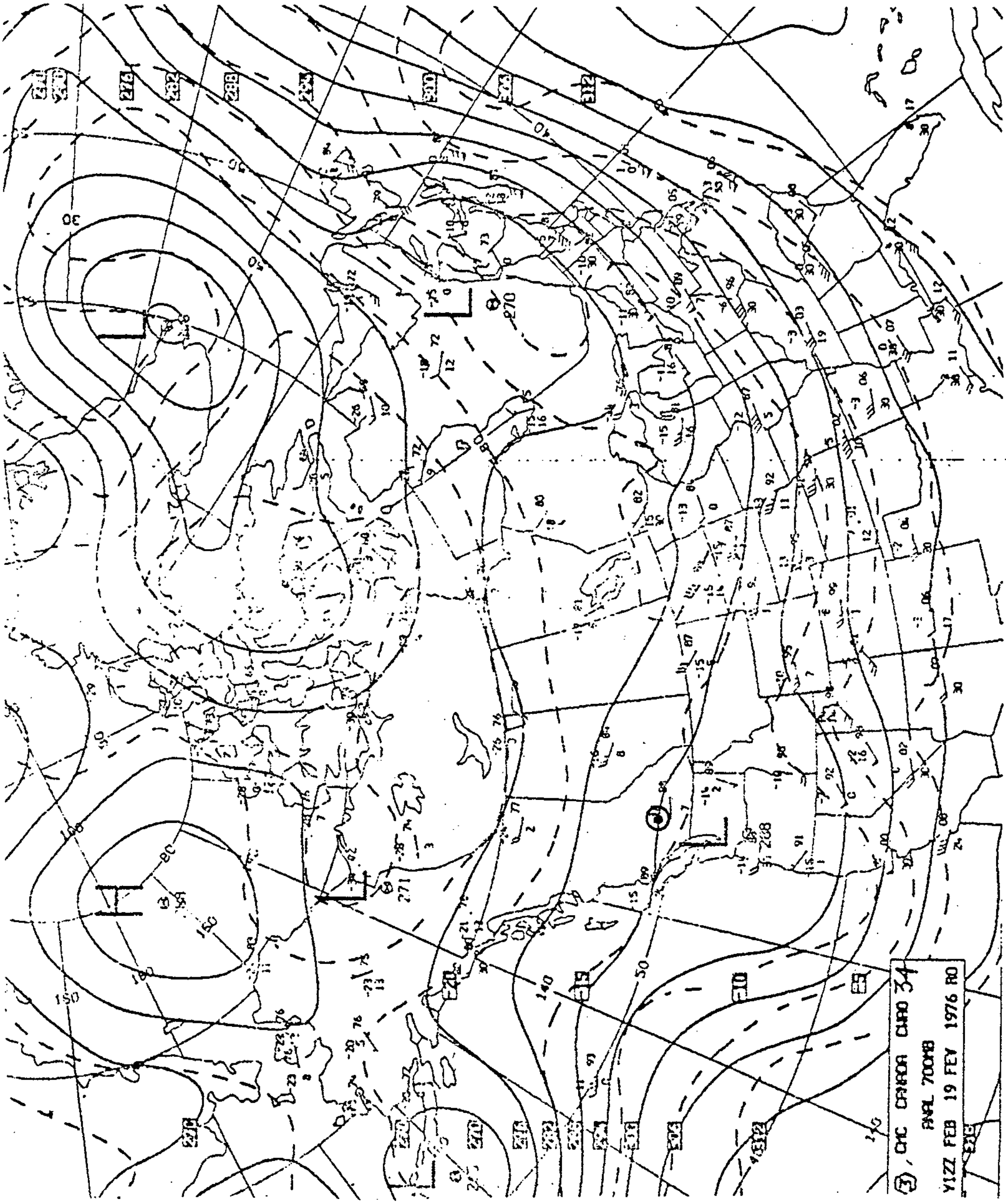


Figure 4.1-1 Surface and 700 mb maps for Test 1, February 19, 1976.

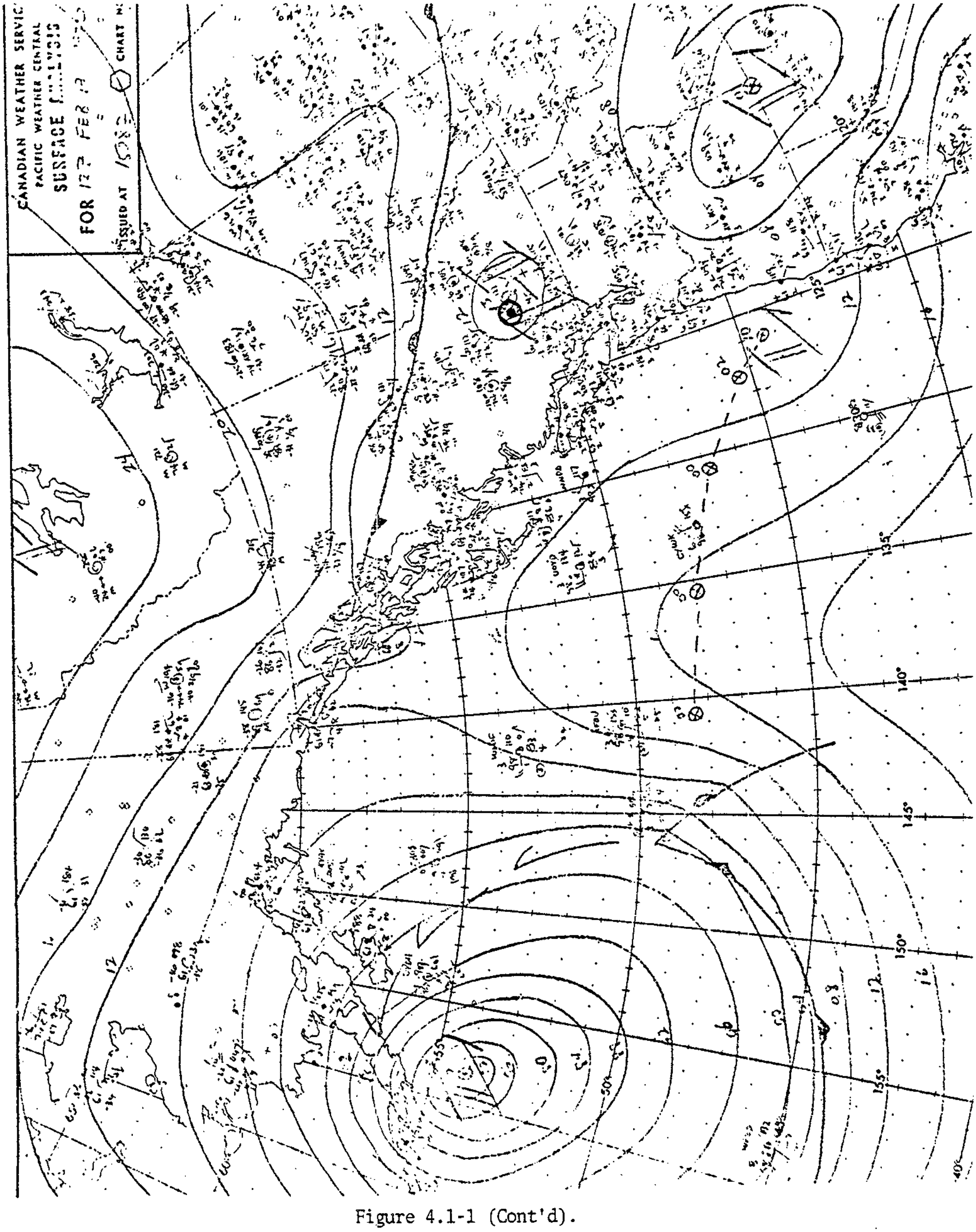


Figure 4.1-1 (Cont'd).

stream far to the south, crossing the Pacific coast in northern California. This situation produced light winds aloft which contributed to the development of stable conditions in Hat Creek.

4.1.2 Meteorological Parameters for Test 1. Meteorological parameters measured in the test area during the first plume simulation consisted of temperature lapse rates and winds at the surface and aloft. Temperature aloft was measured using minisondes and the NAWC airborne data acquisition system. Winds aloft were measured by simultaneously tracking pilot balloons with two theodolites. Surface winds were measured by the B. C. Hydro wind monitoring network.

The temperature profiles measured at various times on the day of the test are presented in Figures 4.1-2, 4.1-3, and 4.1-4. The most important feature of the profiles is a deep isothermal layer which was evident on all of the soundings taken during the tracer dissemination. The first sounding taken at 0710 PST showed the isothermal layer extending from 1150 m to 1650 m MSL. A strong inversion was measured below 1150 m and an adiabatic layer was found above 1650 m. The sounding taken at 0800 PST was quite similar. By 0940 PST, about the time the tracer release began, the inversion had been eroded by surface heating, extending the isothermal layer down to 1000 m MSL with an adiabatic layer below. By 1050 PST, just after the end of tracer dissemination, the isothermal layer had been eroded to above 1200 m MSL. A sounding taken at the site at 1230 PST showed further erosion by surface heating. Soundings taken by the NAWC airborne data acquisition system at other locations in the area showed similar profiles (see Figure 4.1-4).

The surface wind data for Test 1 are given in Volume II, Field Data. These show that surface winds were very light during the tracer release and plume dispersion. Light down-valley flow persisted until about 1200 PST when up-valley flow

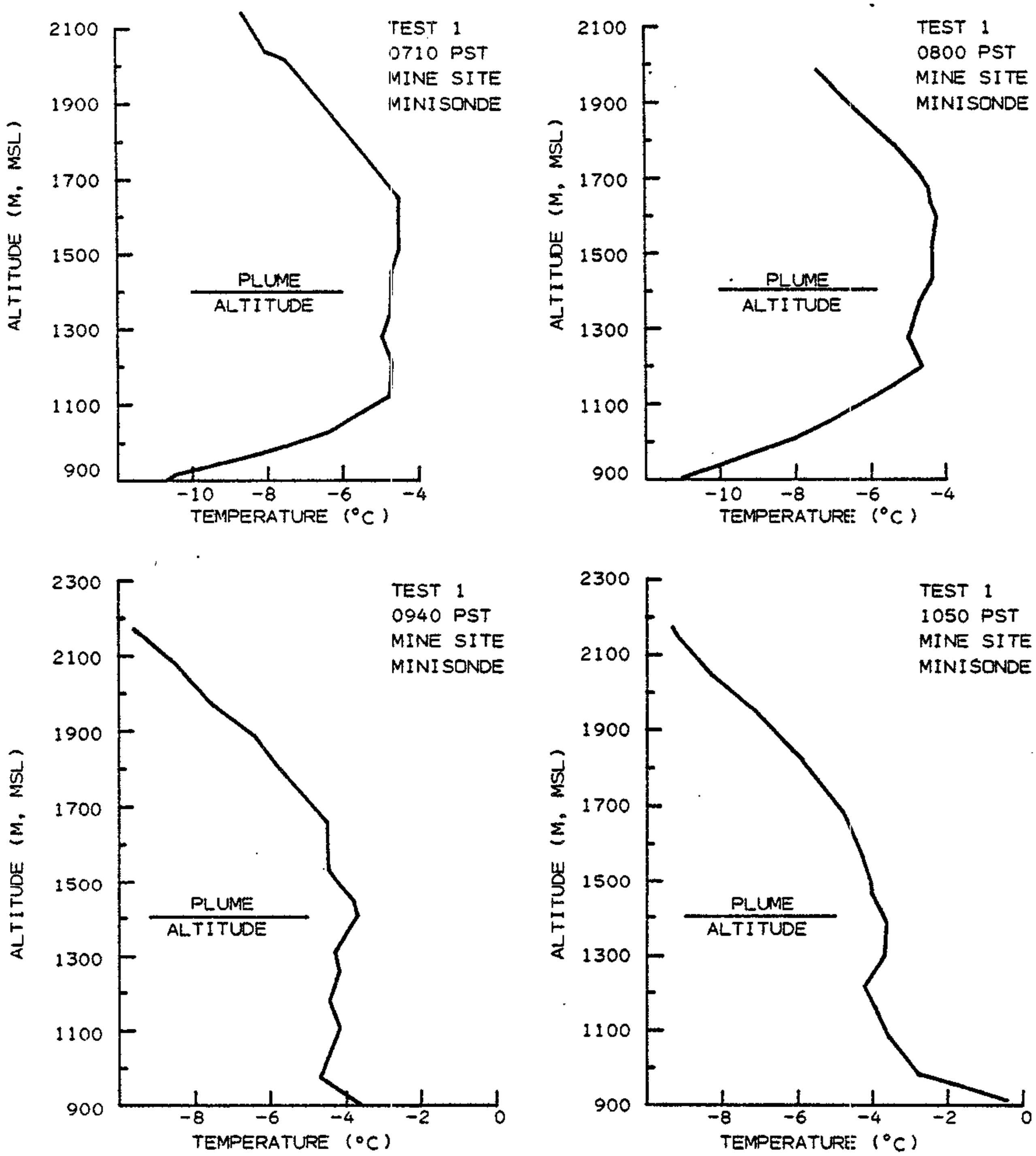


Figure 4.1-2 Vertical temperature profiles measured using minisondes during Test 1.

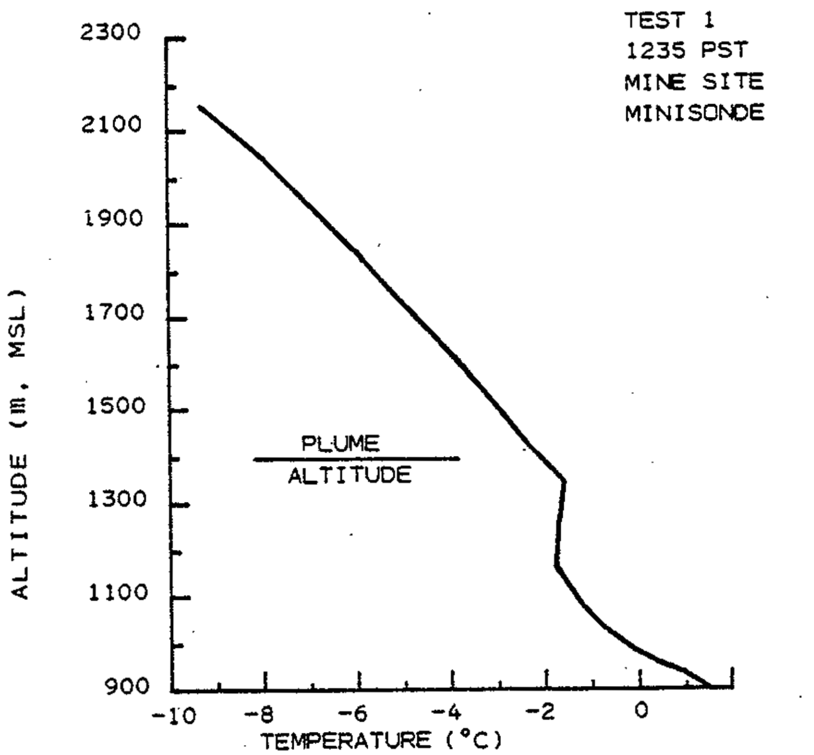


Figure 4.1-2 (Cont'd).

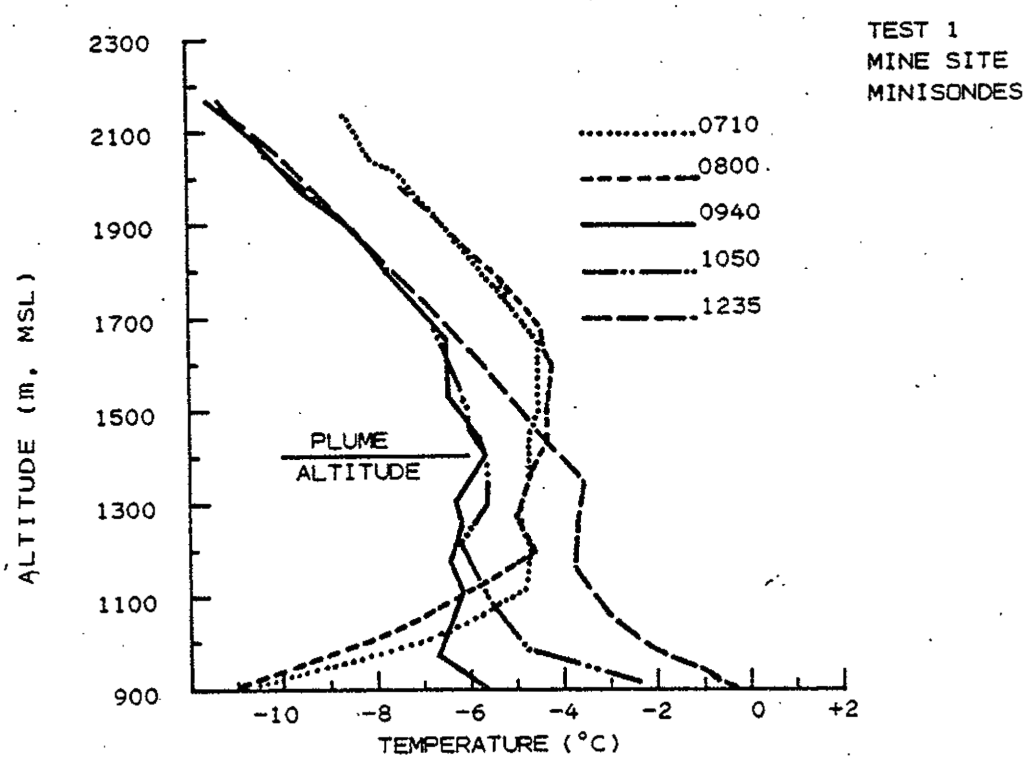


Figure 4.1-3. Superimposed Test 1 minisonde soundings.

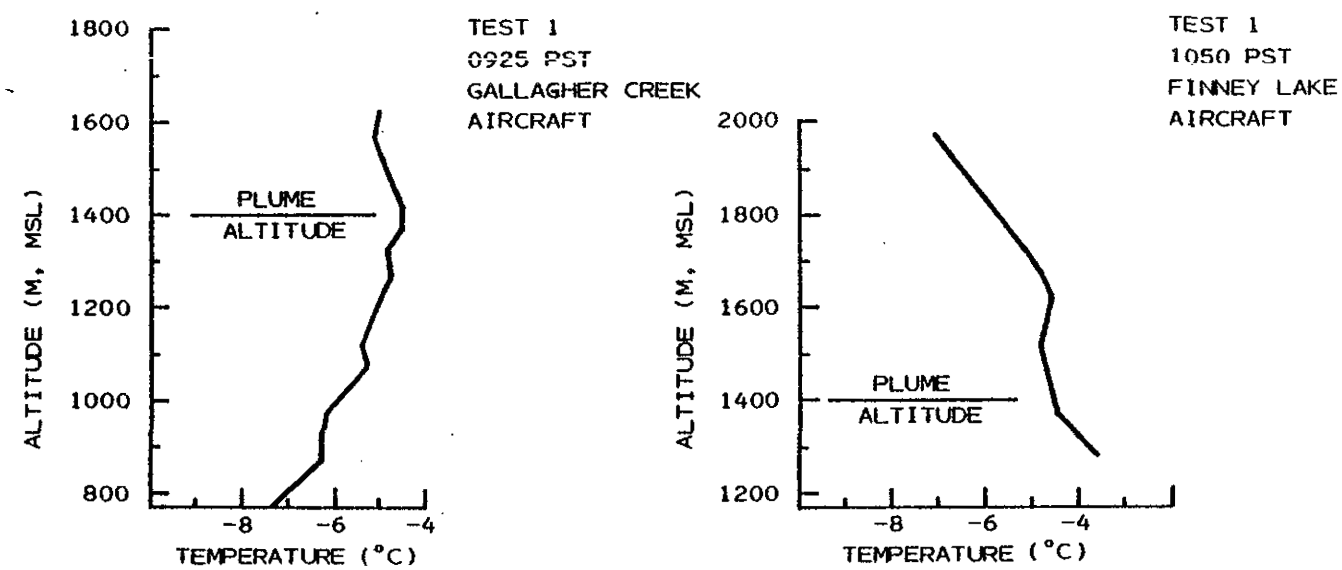


Figure 4.1-4 Vertical temperature profiles measured by the NAWC aircraft system during Test 1. Gallagher Creek is 9 km northeast and Finney Lake is 4 km southwest of the source location.

began. Low lying sites showed wind direction to be generally in line with terrain orientation.

The winds aloft measurements consisted of nine double-tracked pilot balloon releases. These showed that the tracer plume was disseminated near the top of a deep layer of light (less than 1 m/s) and variable winds. This layer coincided with the isothermal layer noted in the temperature soundings. After the end of dissemination the winds slowly increased in speed to greater than 2 m/s after 1130 PST. During that time the wind direction became predominantly northerly. These wind observations agree well with the visual observations made of the oil-fog plume. The winds aloft measurements made during Test 1 are presented in Figures 4.1-5 (direction) and 4.1-6 (speed).

4.1.3 <u>Tracer Dissemination, Test 1</u>. The release parameters for Test 1 are contained in Table 4.1-1 below.

Table 4.1-1 Duration and source strength of tracer release number 1.

Location: Valley Site
Altitude: 1400 m MSL
Simulated Stack Height: 183 m
Stability Classification: E

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	09:36:30	10:30:38	17,479	5.38
Oil Fog (1)	09:36:30	10:09:40	109,800	55.2
Oil Fog (2)*	10:30:30	10:30:38	N/A	N/A

* The oil fog from the second release is not used for quantitative tracking due to the different souce strength generated by this system.

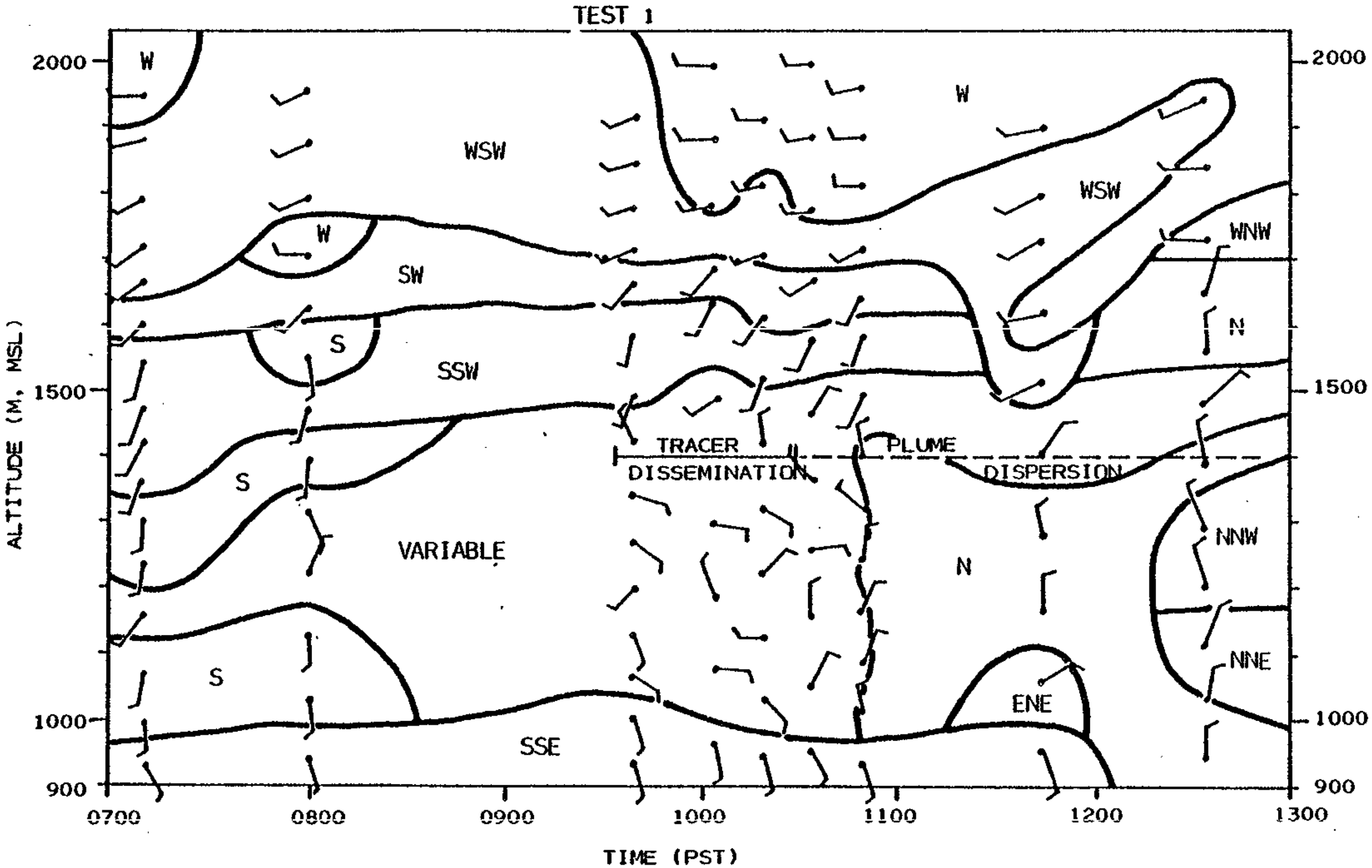


Figure 4.1-5 A time versus altitude display of wind directions aloft measured during Test 1. Barbs indicate wind direction only.

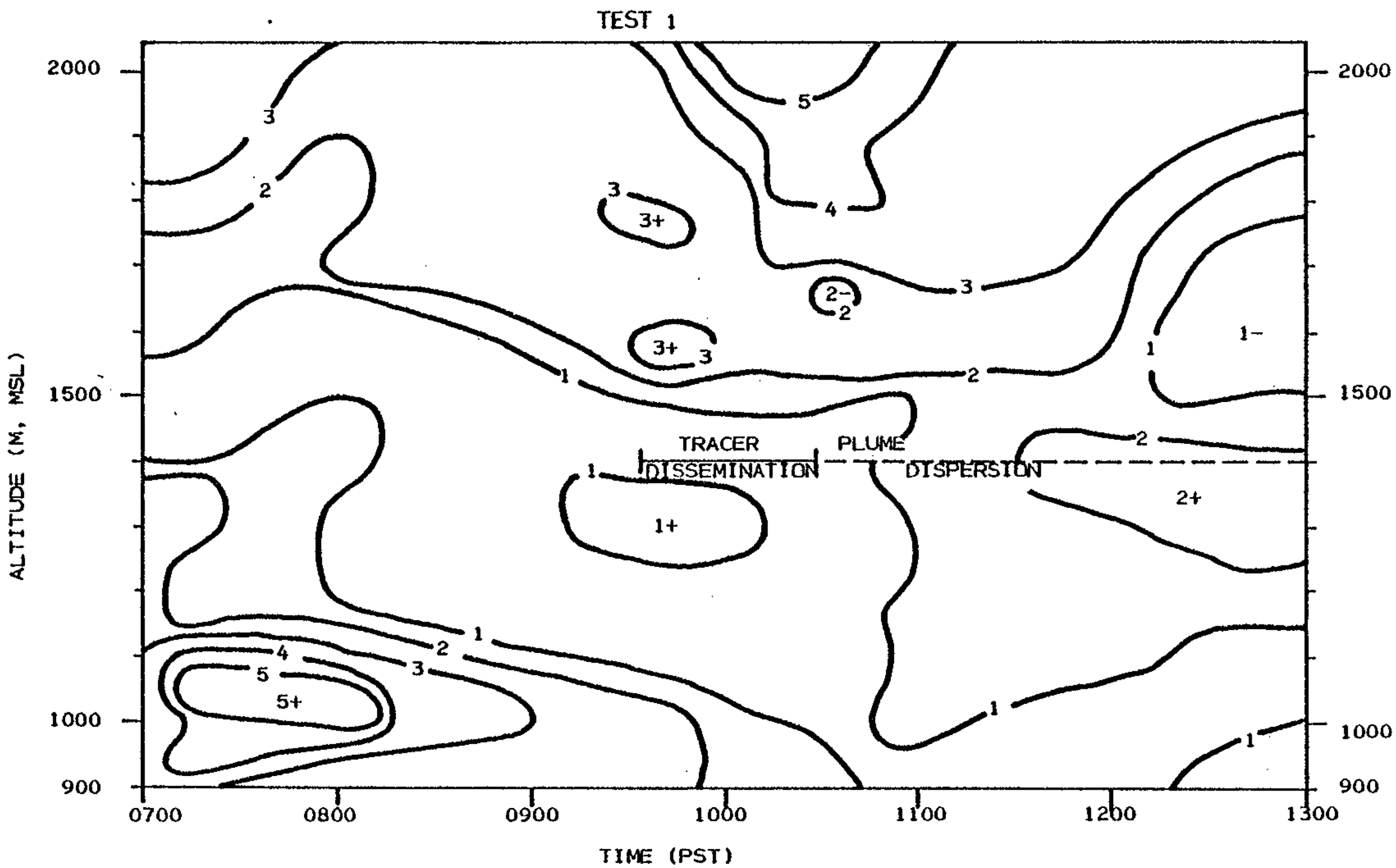


Figure 4.1-6 A time versus altitude display of wind speeds aloft measured during Test 1. Wind speeds are given in m/s.

4.1.4 Visual and Photographic Observation of the Oil-Fog Tracer for Test 1. The transport of the oil-fog plume during the first part of the test was generally toward the west but quite complex. The initial transport appeared to be toward the south, but after a few minutes, the transport shifted to a northwesterly direction (see Figure 4.1-7). For the first 30 to 40 minutes of the test, the transport was generally toward the west with the plume spreading extensively (see Figure 4.1-8). In that time interval the plume spread about 5 km from north to south while it was transported about 3 km across the valley. Figure 4.1-9 shows that plume transport pattern.

During the last 20 to 30 minutes of the release, the plume transport pattern became even more varied, but was generally toward the east and northeast. Figure 4.1-10 shows the plume moving down the Lower Hat Creek Valley, and Figure 4.1-11 shows the eastward movement of the plume near the source. During the last few minutes of tracer dissemination, there was negligible transport and the plume became quite concentrated near the source. That lack of transport apparently marked the transition from a weak down-valley flow to weak up-valley flow. After the dissemination ended, the plume was transported toward the south (see Figure 4.1-12). That southward transport seemed to be general all across the valley. Figure 4.1-13 shows the plume spread in a thin layer across the entire valley and moving slowly southward up the valley.

The movement of the plume throughout Test 1 was varied and complex. Figure 4.1-14 shows the approximate outline of the visible oil-fog plume at three particular times of interest during the test.

4.1.5 Aerial Oil-Fog Measurements. Aerial sampling for Test 1 was carried out between 0958 and 1120 PST. One comprehensive set of crosswind passes was made in a north-south oriented line

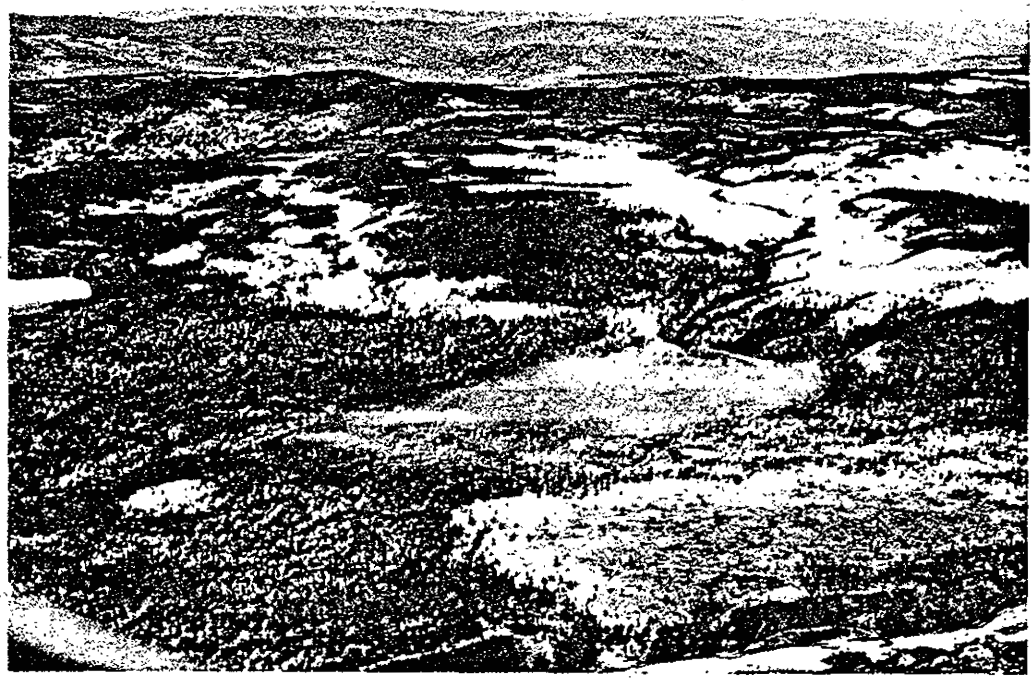


Fig. 4.1-7 A photograph of the Test 1 plume taken at 0947 PST. The view is toward the east.

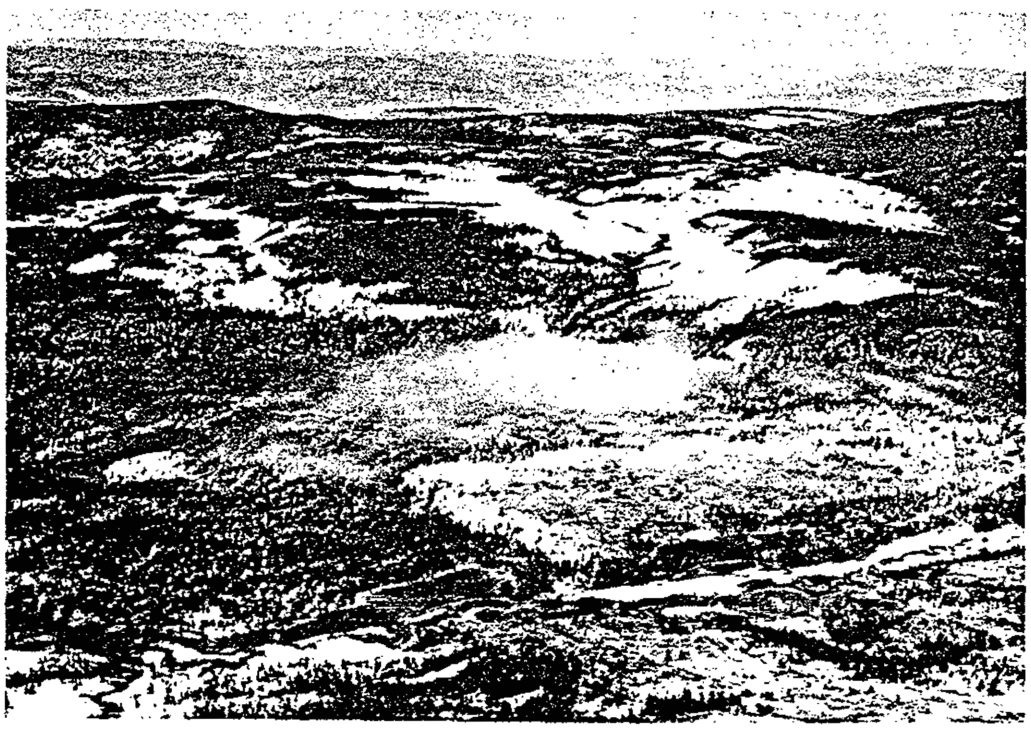


Fig. 4.1-8 A photograph of the Test 1 plume taken at 0953 PST. The view is toward the east. Note that the plume stretches across the entire frame. The source is in the center of the photograph.

Fig. 4.1-9   A photograph of the Test 1 plume taken at 1014 PST. The view is toward the south. The source is on the left edge of the picture and leading edge of the plume is near Finney Lake on the right edge of the frame.

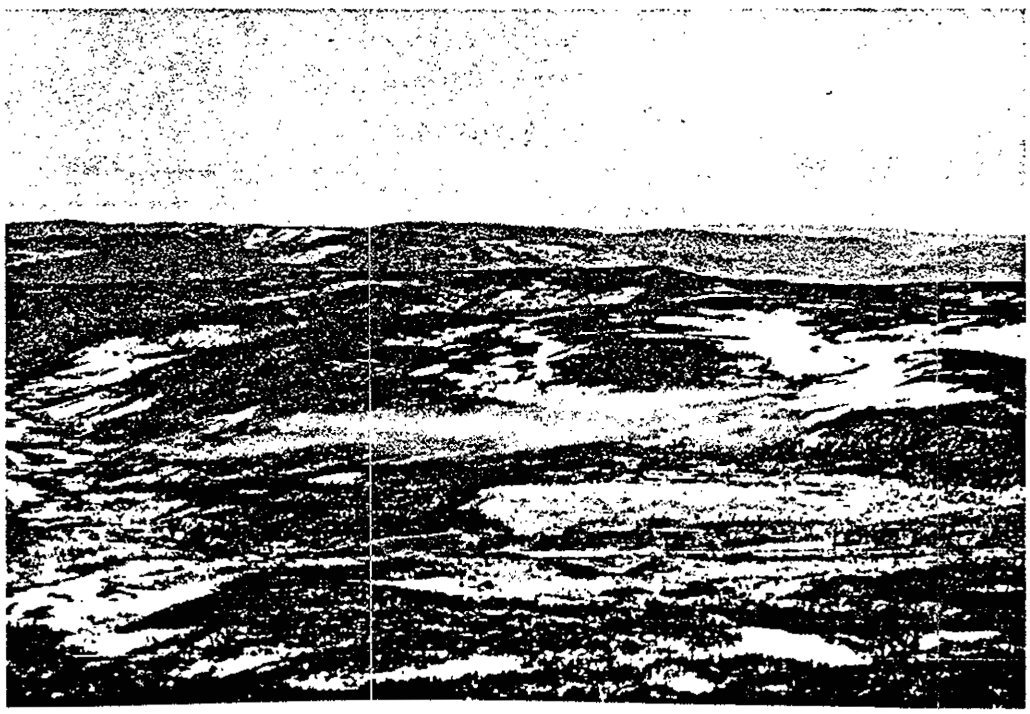


Fig. 4.1-10   A photograph of the Test 1 plume taken at 1019 PST. The view is toward the east-northeast.

Fig. 4.1-11 A photograph of the Test 1 plume taken at 1034 PST. The view is toward the south. The source is on the right (west) side of the picture.

Fig. 4.1-12 A photograph of the Test 1 plume taken at 1051 PST. The view is toward the east. The source area is left of the center of the picture.

Fig. 4.1-13 A photograph of the Test 1 plume taken at 1151 PST. The view is toward the south (up the valley).

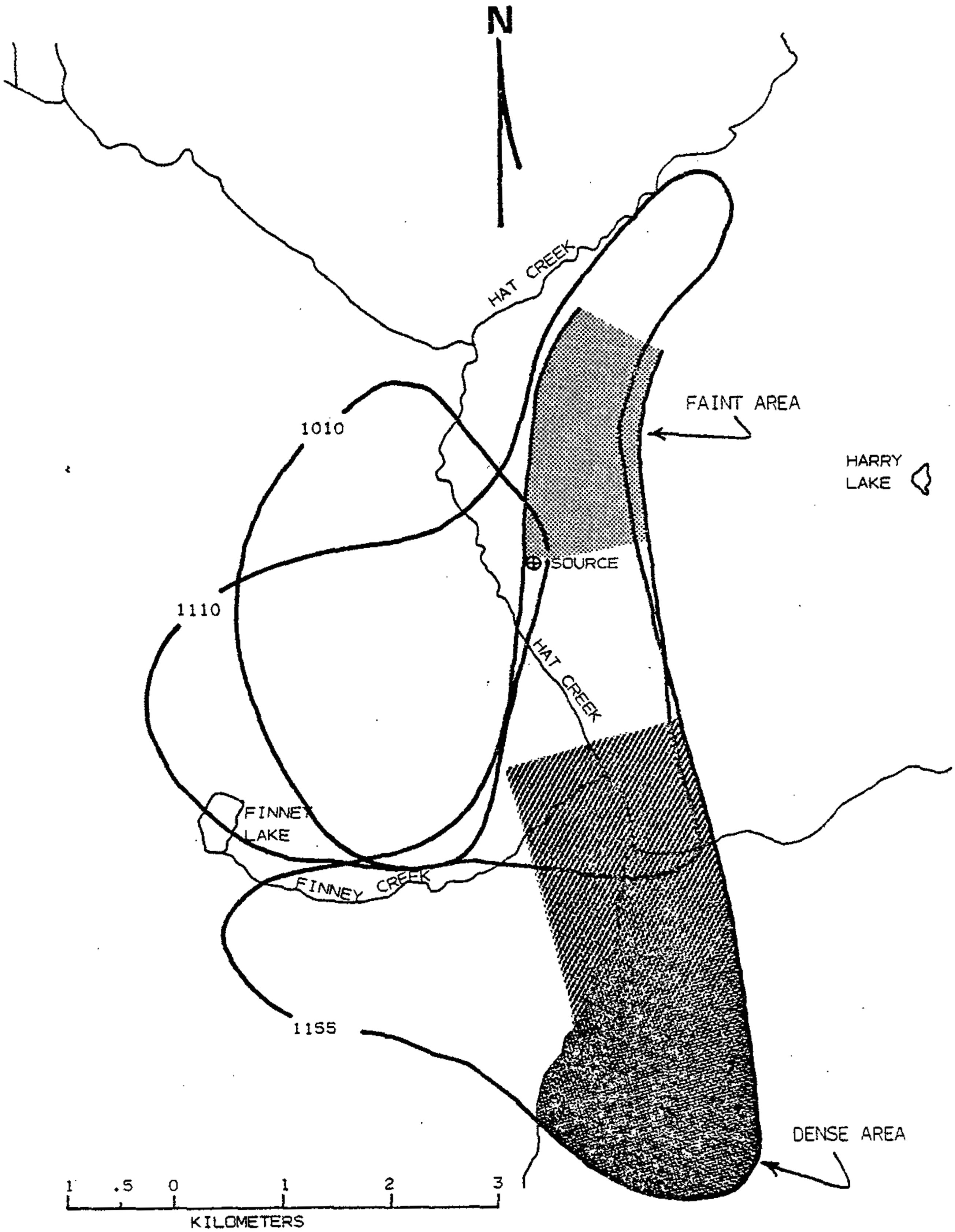


Figure 4.1-14 A map showing the approximate shape and position of the Test 1 visible oil-fog plume at 1010, 1110, and 1155 PST.

passing approximately 1.5 km west of the release point. Two less extensive plume tracking patterns were flown: one, a north-south crosswind pattern 3 km west of the release; and the other, a traverse pattern across Hat Creek Valley (east-west) from Medicine Creek to near Finney Lake. The location of these patterns is shown in Figure 4.1-15. Incidental oil-fog data were gathered during a temperature sounding at Finney Lake. Oil-fog concentration values (b_{scat}) were converted to gm^{-3} SO_2 per 2000 MW (net) generating capacity in the manner outlined in Section 3, Research Method.

The first set of oil-fog measurements was made between 0958 and 1030 PST, at altitudes between 1435 and 1280 m MSL. The maximum measured concentration was equivalent to 19,970 μgm^{-3} SO_2. This was found at 1370 m MSL, 30 m below release altitude, at a point 2.1 km south-southwest of the release. Figure 4.1-16 presents a plot of distance versus concentration for the 1370 m MSL pass. The distances given in the figure correspond to those indicated on the map, Figure 4.1-15. Also shown is a plot of altitude versus maximum concentration for this set of measurements. It can be seen that while the plume was confined to a relatively thin layer ($\sim$ 160 m), it was over 3 km wide, reflecting the stable temperature structure and meandering flow conditions under which this test was conducted.

Analysis of the data for this set of measurements indicates that the values of the horizontal and vertical dispersion coefficients σ_y and σ_z were close to 425 m and 25 m, respectively. Figure 4.1-17 shows these values along with the predicted flat land curves from Turner, 1970. At a distance of 2.6 km (virtual source distance included, see Table 3.1-1), the value of σ_y is approximately 400% of that indicated for an E type stability, while the value of σ_z is slightly less than that indicated for the prevailing conditions.

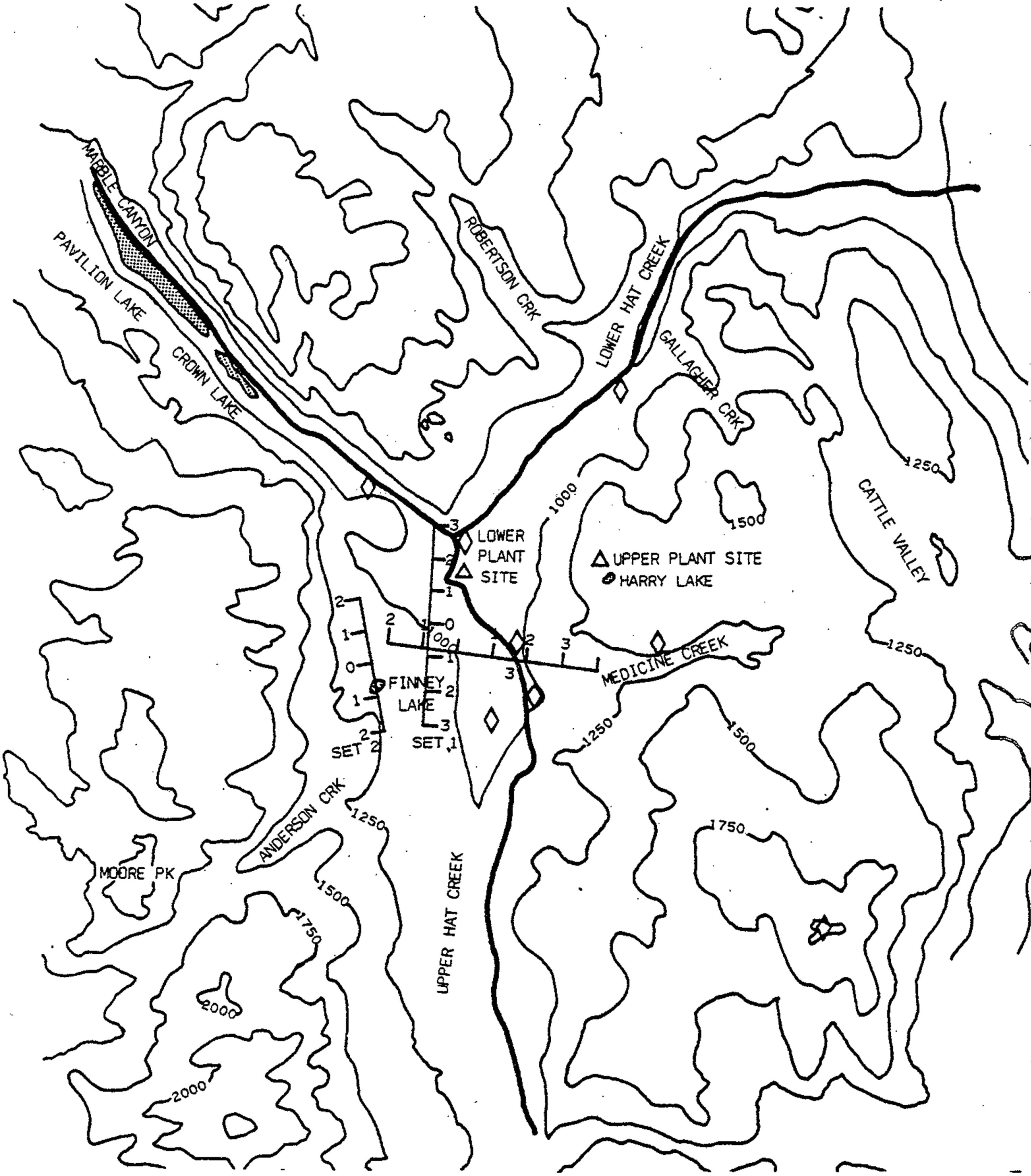


Figure 4.1-15 Location of oil-fog crosswind patterns, Test 1. Distances are in kilometers.

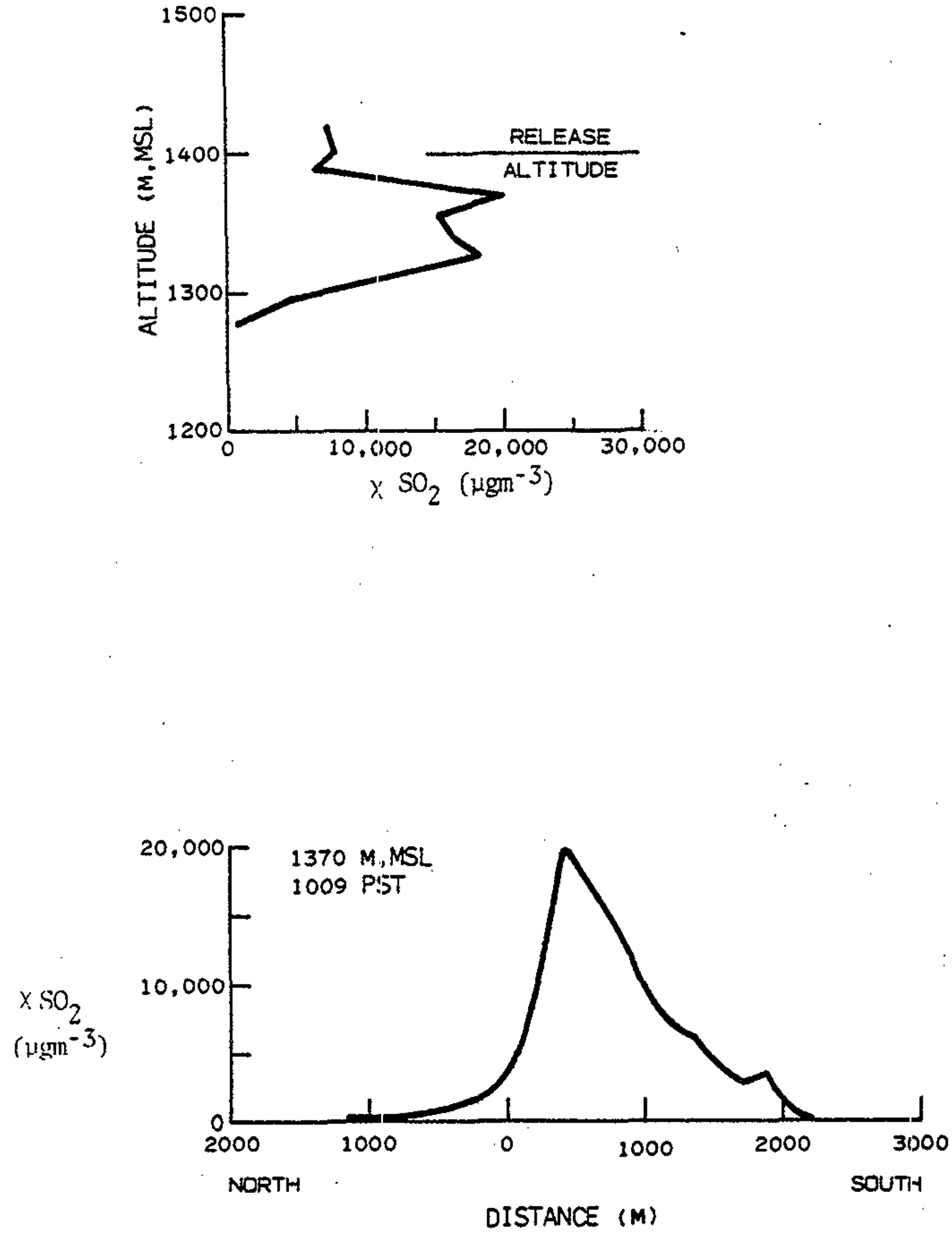


Figure 4.1-16 Horizontal and vertical centerline distributions, Set 1, Test 1.

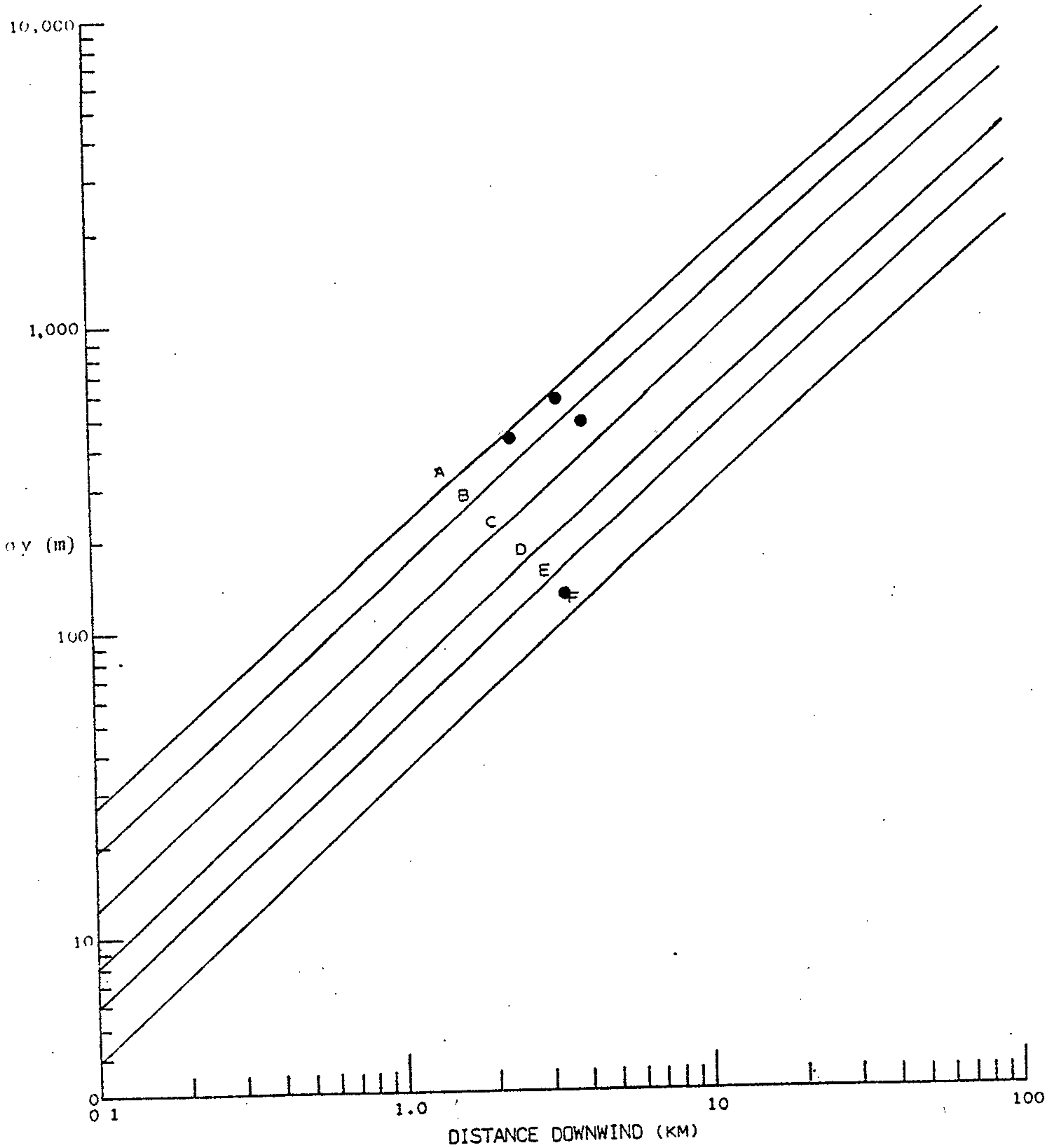


Figure 4.1-17 Measured values of σ_y and σ_z, Test 1.

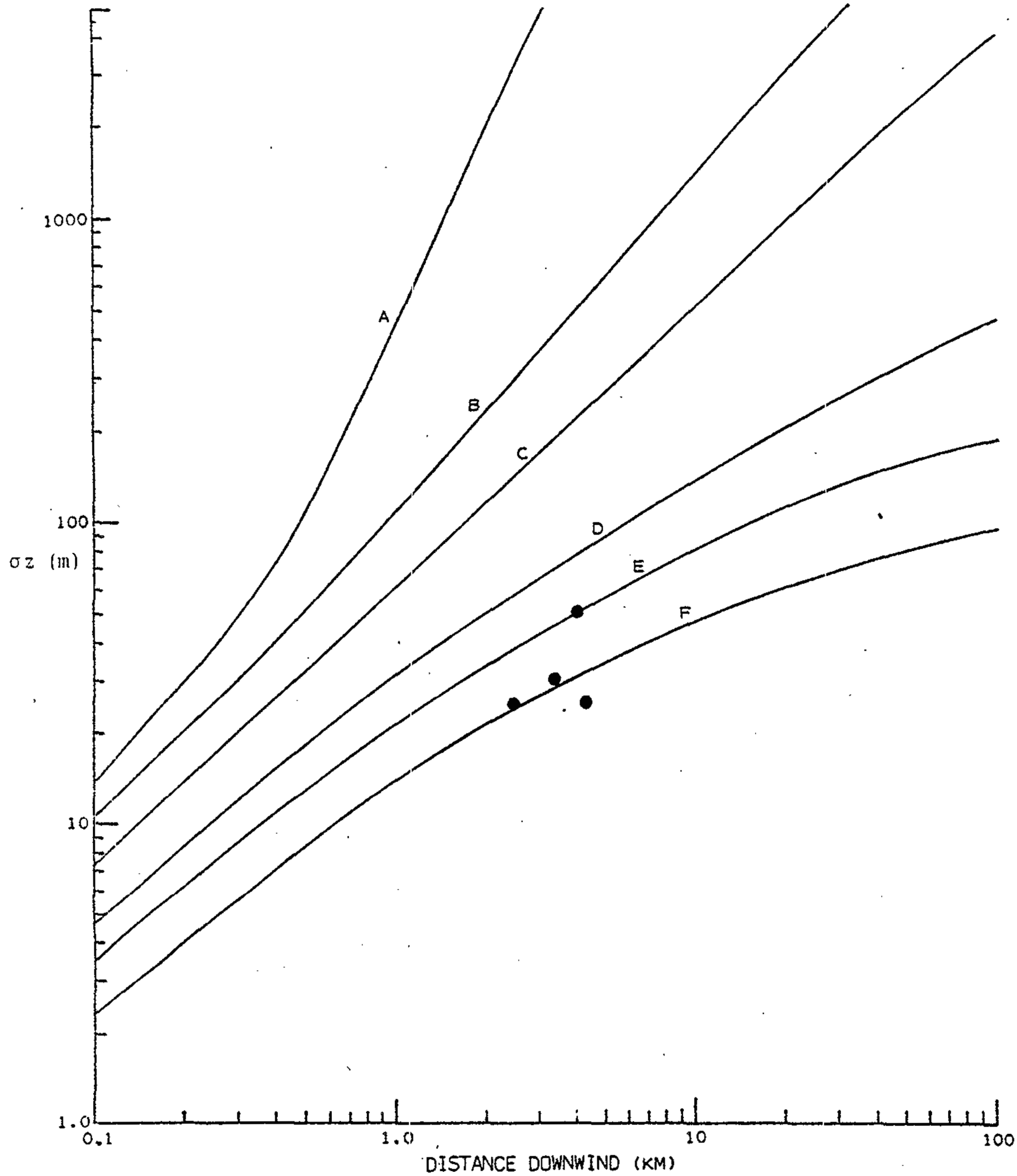


Figure 4.1-17 (Cont'd.)

The peak measured concentration, normalized with respect to wind speed and source strength ($\frac{X\bar{u}}{Q}$) is shown together with the predicted values in Figure 4.1-18. The value indicates an overall dispersion rate close to that of a C-type stability, representing a reduction from the estimated value of about an order of magnitude.

The second set of crosswind patterns was flown between 1040 and 1050 PST from Finney Lake northward as shown in Figure 4.1-15. The maximum concentration was found to be 2315 μgm^{-3} at 1370 m MSL. Slightly lower concentrations were measured at 1355, 1340, and 1325 m MSL. Figure 4.1-19 shows the maximum concentration versus altitude for these passes, as well as a distance versus concentration plot for the 1355 m pass. Measurements of σ_y and σ_z were attempted, though only three passes are available at this location. These values of about 575 m and at least 30 m, respectively, are displayed in Figure 4.1-17. It can be seen that while horizontal diffusion is apparently proceeding much more rapidly than the flatland curves indicate, vertical diffusion is proceeding at a rate close to the nominal value for E stability. A value of $\frac{X\bar{u}}{Q}$ was calculated for the maximum concentration, though it is apparent that no definable centerline existed in the plume at this place and time, and it is shown in Figure 4.1-18.

Some incidental oil-fog data were gathered during a sounding taken near Finney Lake between 1050 and 1055 PST. At this time, the plume layer was found to be between about 15 m AGL (1250 m MSL) and 1400 m MSL, though concentrations near the ground were marginally within instrument resolution (0.1 $b_{scat} \approx 290\ \mu gm^{-3}\ SO_2$). The maximum concentration measured was 1736 μgm^{-3} at an altitude of 1310 m MSL. The corresponding value of $\frac{X\bar{u}}{Q}$ is displayed in Figure 4.1-18. While the oil-fog data gathered during this sounding do not lend themselves to a computation of σ_y, an estimate of about 25 m may be made for σ_z. This value is shown in Figure 4.1-17.

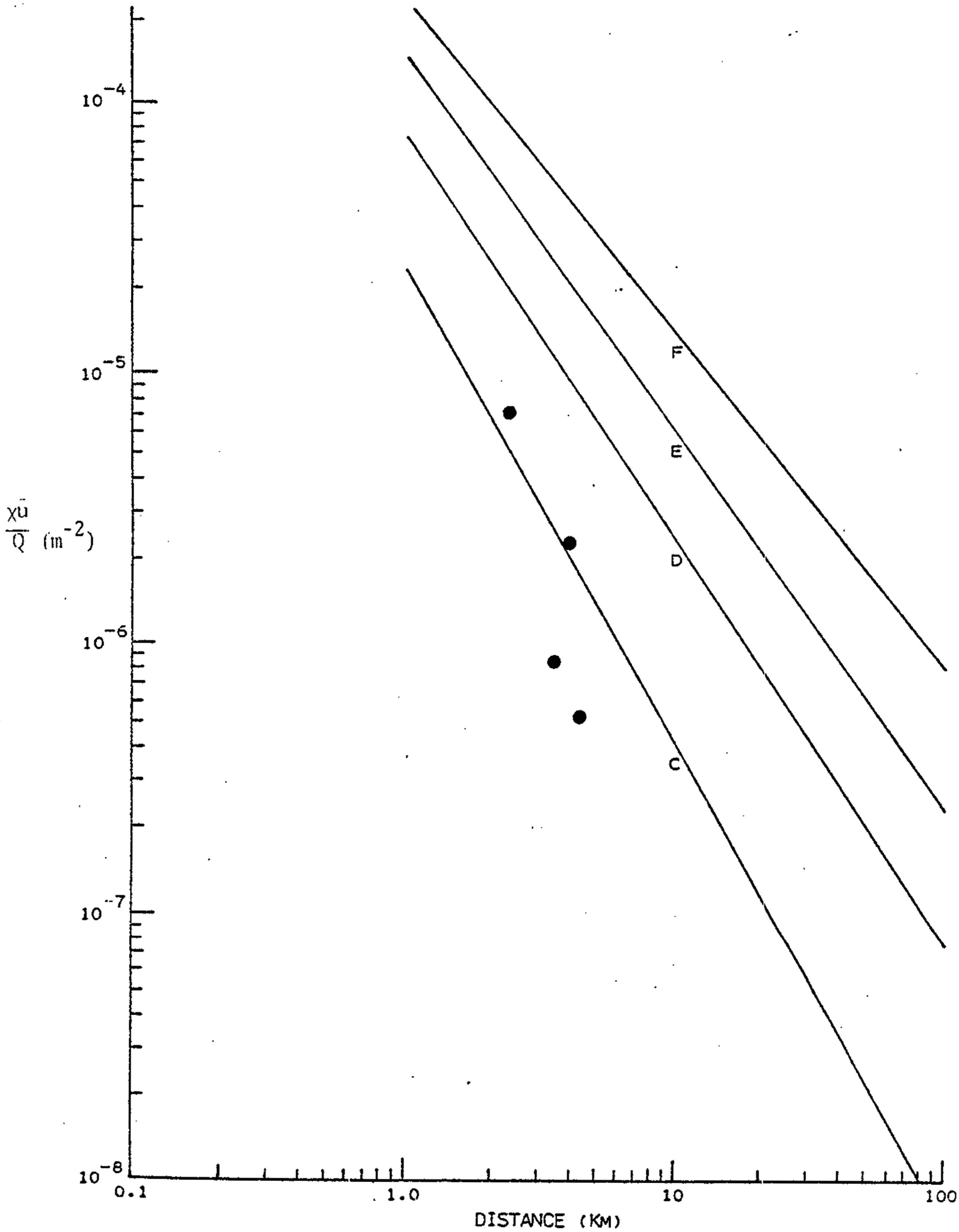


Figure 4.1-18 Measured values of $\frac{\chi u}{Q}$, Test 1.

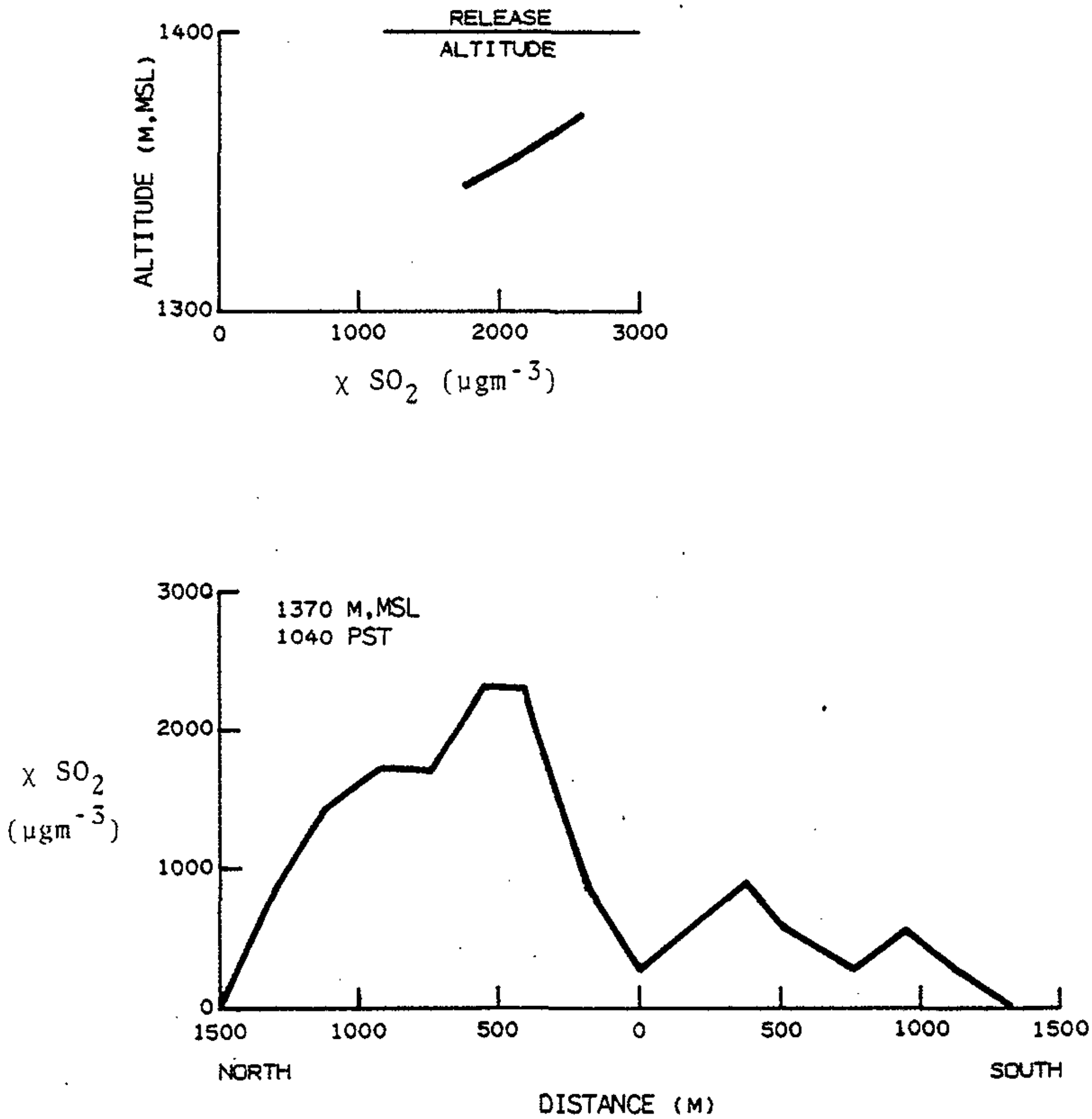


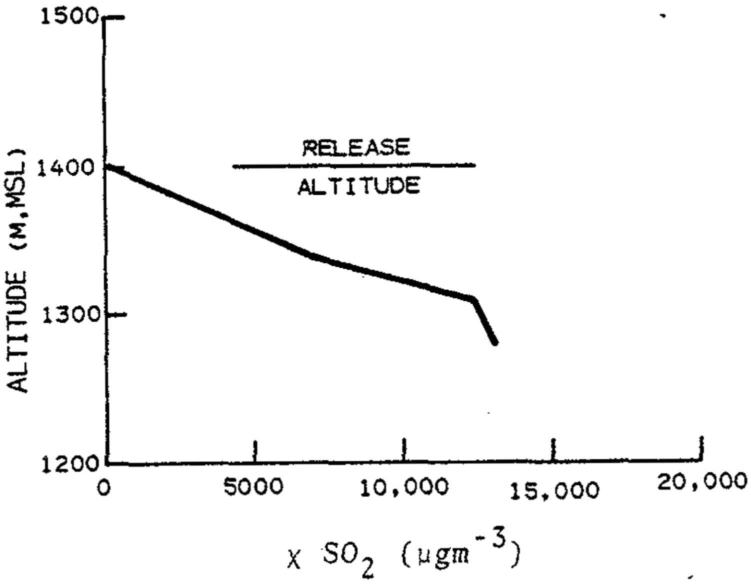
Figure 4.1-19 Horizontal and vertical centerline distributions, Set 2, Test 1.

A third set of crosswind patterns was flown between 1100 and 1125 PST extending from Medicine Creek westward to near Finney Lake as shown in Figure 4.1-15. Six passes were made at altitudes between 1525 and 1280 m MSL, with the maximum concentration of 13,030 μgm^{-3} being found at 1280 m MSL at a point 3.8 km south of the release. Figure 4.1-20 presents a plot of altitude versus maximum concentration for each of these six passes as well as a display of distance versus concentration for the pass at 1280 m MSL. Of particular note is the fact that virtually the entire plume was confined to a layer below the release altitude. This behavior of a sinking plume layer with little vertical mixing was noted again in a summer test, number 12.

An analysis of the flight-data suggest that the values of σ_y and σ_z were near 275 m and at least 50 m, respectively, for set 3. Since the centerline altitude was not defined with certainty, σ_z can only be specified as a lower limit. These values are plotted in Figure 4.1-17 and indicate that horizontal spreading is still two to three times greater than shown for the appropriate flat land curves and that the rate of vertical diffusion is slowly increasing to a point close to that shown for E stability.

The value of $\frac{X\bar{u}}{Q}$ corresponding to the maximum measured concentration for this set of crosswinds has been plotted in Figure 4.1-18. Here it can be seen that the rate of dispersion for this stable plume has continued to fall close to that shown for C type stability over flat ground. This represents a ten-fold increase in dilution over the predicted value for an E type atmosphere.

4.1.6 <u>Aerial SF_6 Measurements</u>. Figure 4.1-21 shows the location of aerial SF_6 samples taken during Test 1. Table 4.1-2 gives the altitudes MSL and AGL of each sample, sampling time, and measured concentration in μgm^{-3} SO_2 per 2000 MW generating capacity. The highest measured concentration found during



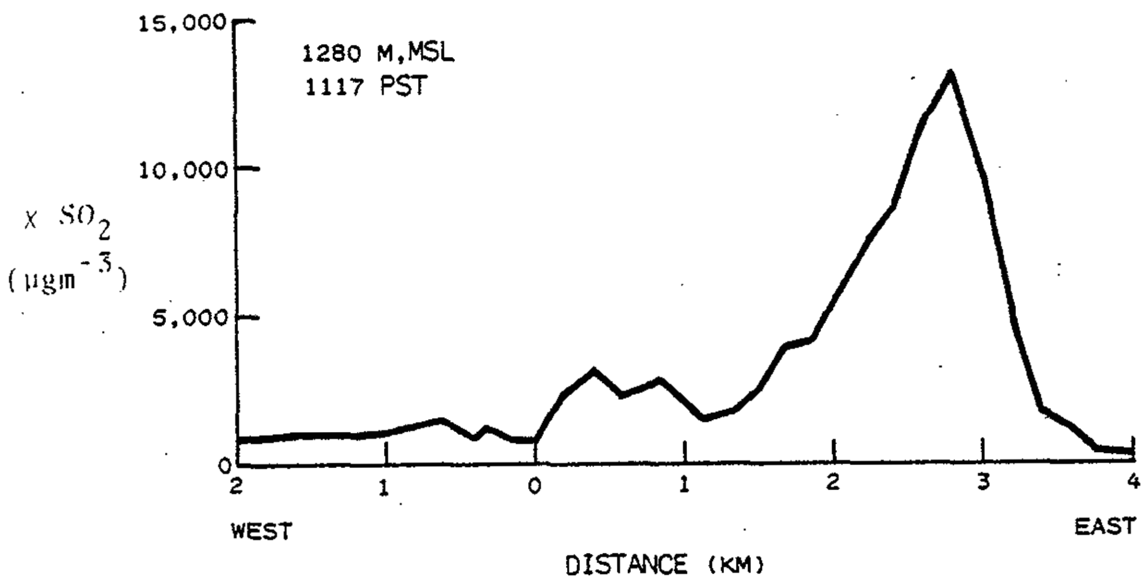


Figure 4.1-20 Horizontal and vertical centerline distributions, Set 3, Test 1.

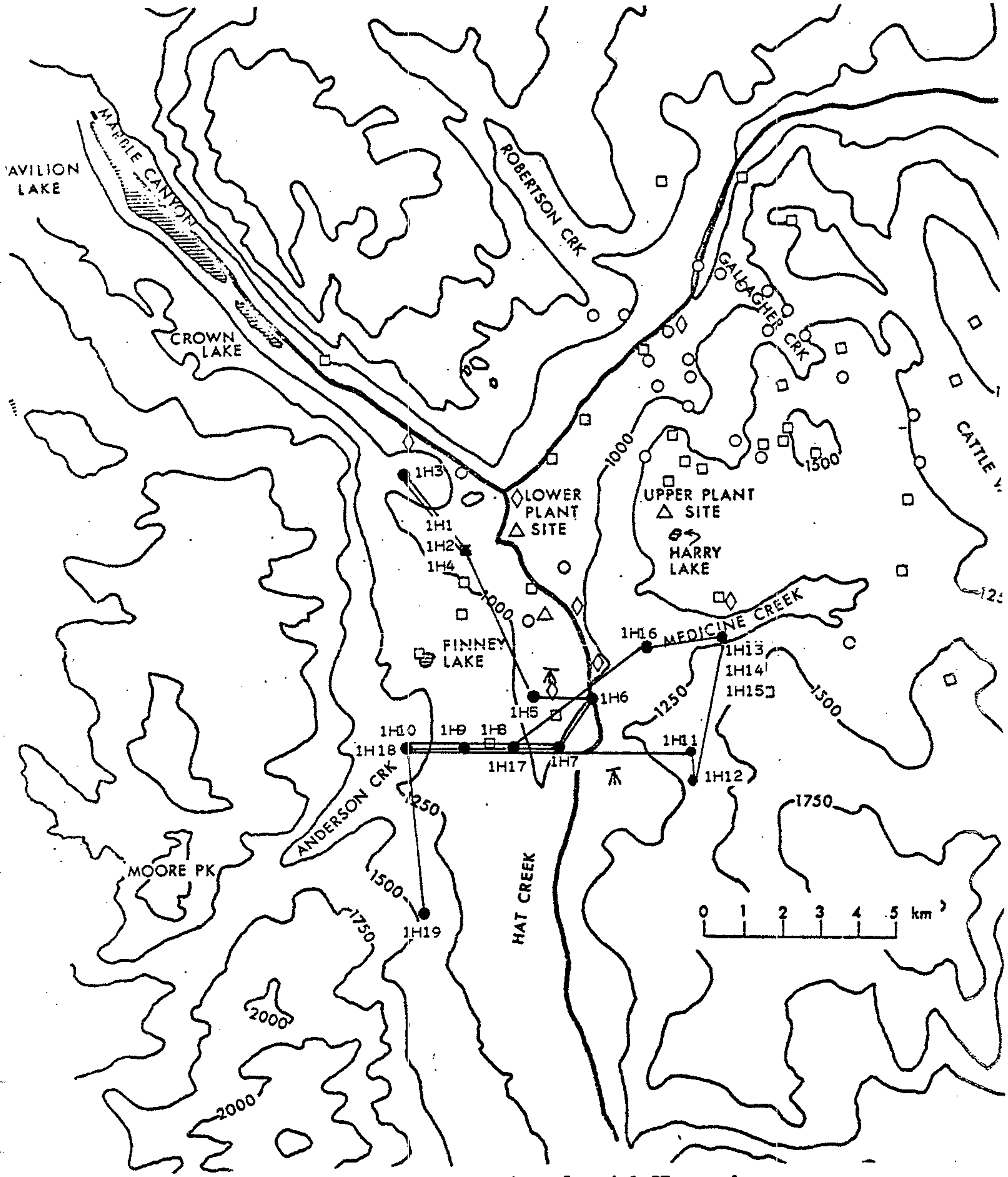


Figure 4.1-21 Location of aerial SF_6 samples.

Table 4.1-2. Aerial SF_6 sample information.

Sample No.	Distance from Release (km)	Altitude (m)		Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3})	
		MSL	AGL			Ambient	NTP
1H1	1.7	1340	415	1023	1	0	0
1H2	1.7	1310	385	1028	1	4280	4652
1H3	3.6	1250	0	1032	2	0	0
1H4	1.7	1130	205	1038	2	27945	29887
1H5	4.4	1310	320	1045	1	174	189
1H6	4.4	1035	25	1055	1	0	0
1H7	5.5	1065	65	1122	2	0	0
1H8	5.5	1065	40	1125	2	174	189
1H9	5.7	1090	10	1129	1.5	264	287
1H10	6.4	1140	15	1135	2	0	0
1H11	6.5	1315	15	1140	2	0	0
1H12	7.5	1315	15	1142	2	0	0
1H13	5.3	1340	140	1145	1	0	0
1H14	5.3	1260	60	1148	1	0	0
1H15	5.3	1200	0	1154	1	0	0
1H16	4.1	1065	15	1157	1	0	0
1H17	5.5	1035	35	1200	1	0	0
1H18	6.4	1140	15	1204	1	566	615
1H19	10.6	1490	5	1208	3	1966	2137

aerial sampling was 27,946 μgm^{-3} SO_2, approximately 4 km south of the release point, at an altitude of 1310 m MSL (320 m AGL).

Two cross valley transects were made (samples 7, 8, 9, 10, 17, and 18) approximately 5.9 km up valley from the release. The first showed measurable SF_6 only at the westernmost sites at altitudes between 1065 and 1140 m MSL (15-65 m AGL). The second transect along the same line, made about 30 minutes later, shows a similar distribution. This observation agrees with data from the ground network, indicating that ground concentrations reached their maximum well south of the release point and that measurable ground concentrations occurred at the highest sites first, probably on the hills along the western side of the valley.

The samples taken in Medicine Creek and over the eastern slopes of the valley (samples 11-16) yielded no measurable concentrations of the tracer gas. Data from the tracer aircraft, indicating very low concentrations this far up the Medicine Creek, concur with these findings. The fact that no measurable concentration was found in samples 1H11, 1H12, and 1H16 indicates that the plume had not yet mixed to the ground along the east side of the valley, though fumigation was under way on the west side.

Temperature soundings indicate that the two highest measured concentrations from aerial SF_6 samples were found in the stable layer and thus do not indicate likely maximum ground concentrations.

4.1.7 Surface SF_6 Measurements. A total of nine ground samplers were deployed during Test 1. Six of these were sequential samplers taking half-hour samples, while three were single samplers which took continuous samples of up to three-hour duration. Hand-sequenced grab samples were also employed for measurements at the mine site. Figure 4.1-22 shows the locations of these samplers, while Table 4.1-3 gives supplementary information

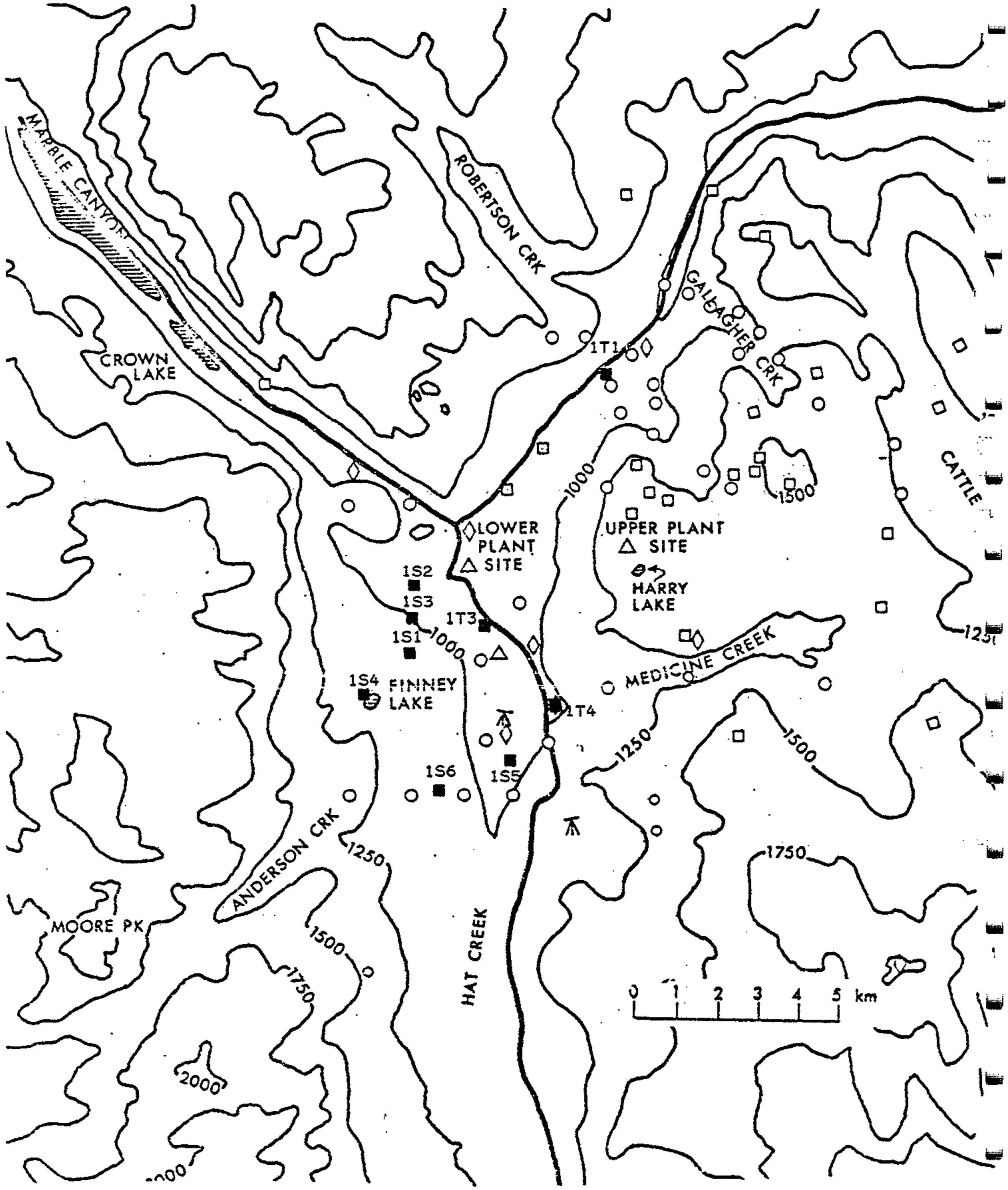


Figure 4.1-22 Location of ground SF_6 samplers.

Table 4.1-3 Surface sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On (PST)	Time Off (PST)	Sampling Time (Min)	XSO_2 (μgm^{-3}) Ambient	NTP
1S1	2.5	1065	1013	1043	30	0	0
			1043	1113	30	0	0
			1113	1143	30	130	141
			1143	1213	30	1050	1141
			1213	1243	30	1310	1424
			1243	1300	17	480	522
1S2	1.6	915	1030	1100	30	0	0
			1100	1130	30	0	0
			1130	1200	30	0	0
			1200	1230	30	0	0
			1230	1300	30	0	0
1S3	2.1	1035	1050	1120	30	0	0
			1120	1150	30	174	189
			1150	1220	30	742	807
			1220	1250	30	786	854
			1250	1310	20	436	474
1S4	4.4	1190	1100	1130	30	130	141
			1130	1200	Malf.	--	--
			1200	1230	30	436	473
			1230	1300	30	436	473
			1300	1315	15	656	713
1S5	4.6	965	1125	1155	30	0	0
			1155	1225	30	264	287
			1225	1255	30	350	380
			1255	1320	30	86	93
1S6	5.5	1065	1135	1205	30	566	615
			1205	1235	30	2358	2563
			1235	1305	30	2968	3226
			1305	1320	Malf.	--	--
1T1	6.0	740	0825	1125	180	174	189
1T3	1.3	920	0900	1145	165	0	0
			1045	1115	30	86	93
			1145	1225	40	0	0
			1225	1350	25	174	189
			1250	1325	35	0	0
1T4	3.8	950	1215	1315	60	174	189

concerning altitude, distance, time, and measured concentrations. The maximum measured ground level concentration over a one-half hour averaging period was equivalent to 2968 μgm^{-3} SO_2 at site 1S6.

As can be seen from the data in Table 4.1-3, there is general agreement among the sampler data that the maximum ground level concentrations occurred between 1200 and 1300 PST and that measurable ground level concentrations appeared between 1100 and 1155 PST. There was a definite trend for the higher samplers to show measurable concentrations earlier than lower samplers, as displayed in Figure 4.1-23. This figure indicates a downward transport rate of about 200 m/hr.

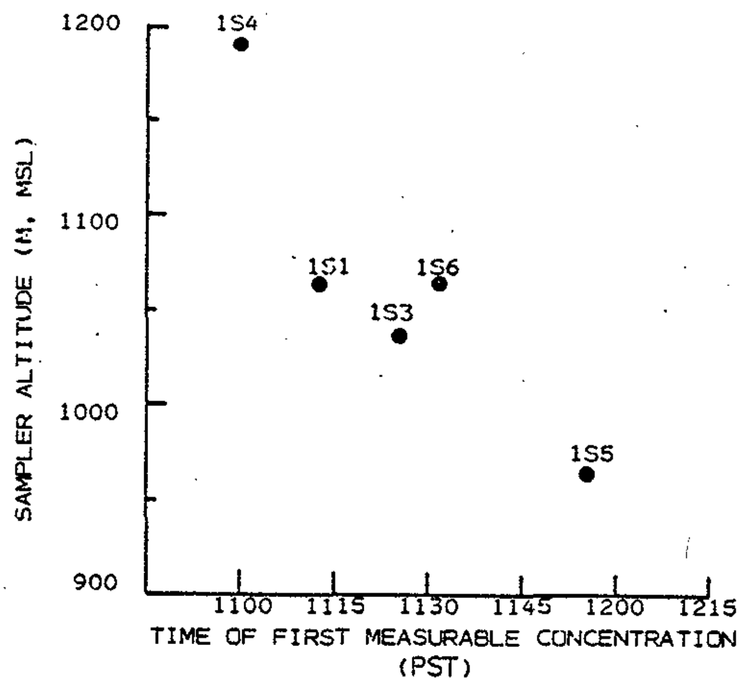


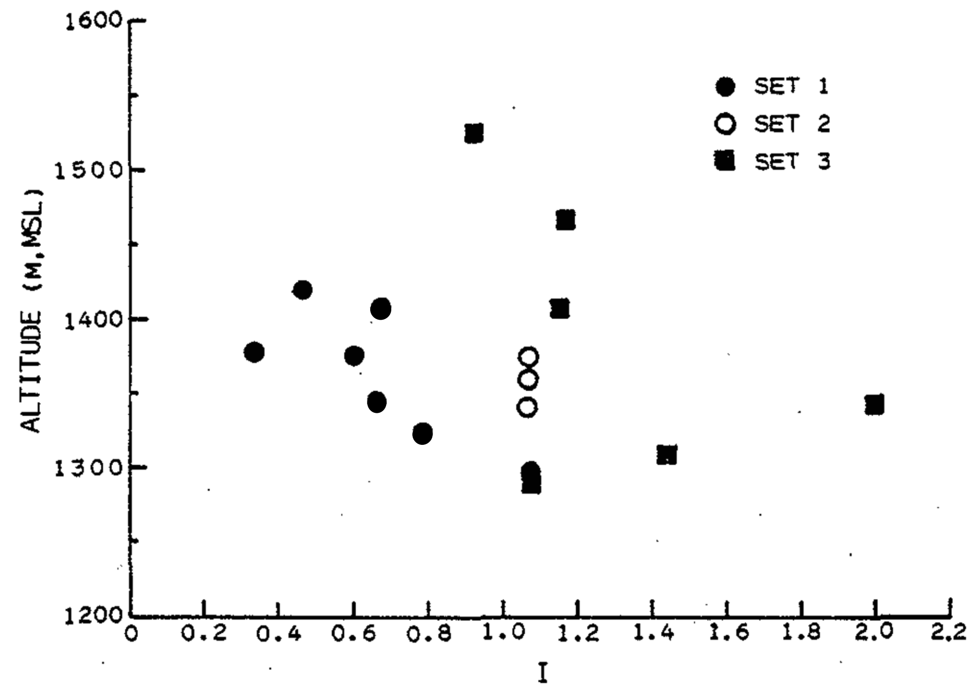
Figure 4.1-23 Sampler altitude vs. time of first measured concentration (time measured from beginning of half-hour sampling period).

Also evident from the pattern of plume impact is a trend for those samplers in a north-south line approximately 2.5 km west of the release site (1S3, 1S1, and 1S6) to receive higher concentrations than other samplers, and for samplers further south to receive more than those to the north. Sampler 1S2 received no measurable SF_6. Due to the site's proximity to the release point, the plume passed over the sampler prior to fumigation.

A comparison of the depicted plume position for 1155 PST (see Figure 4.1-14) and the pattern of tracer impact suggests that a northeasterly flow (up-valley) was well developed at this time near the ground, although such flow was not yet evident at the mine site. As the plume fumigated over the center of the valley, the portions caught in the mixing layer were evidently swept westward and southward and finally reached the ground on the western slopes of the valley.

Site IT1 measured 174 μgm^{-3} over a three-hour period from 0825-1125 PST. This is evidently an indication that a portion of the plume, which initially traveled down-valley, fumigated and moved back up-valley in the mixing layer. The three-hour sample at the mine site (1T3) showed no measurable concentration, though hand-sequenced grab samples indicated low concentrations were present in the area between 1045 and 1115 PST and again between 1225 and 1250 PST. Site 1T4, 4.4 km south of the release, measured 174 μgm^{-3} between 1215 and 1315 PST, supporting the suggestion that impact on the east side of the valley was light.

4.1.8 Turbulence Measurements. The turbulence data gathered during each set of oil-fog patterns were treated as outlined in Section 3.4.1 and are presented in Figure 4.1-24. It can be seen that the values of $\bar{\varepsilon}$ were unexpectedly high during set 1, perhaps reflecting shear-generated turbulence associated with the down valley flow. The values from sets 2 and 3 were typical of stable



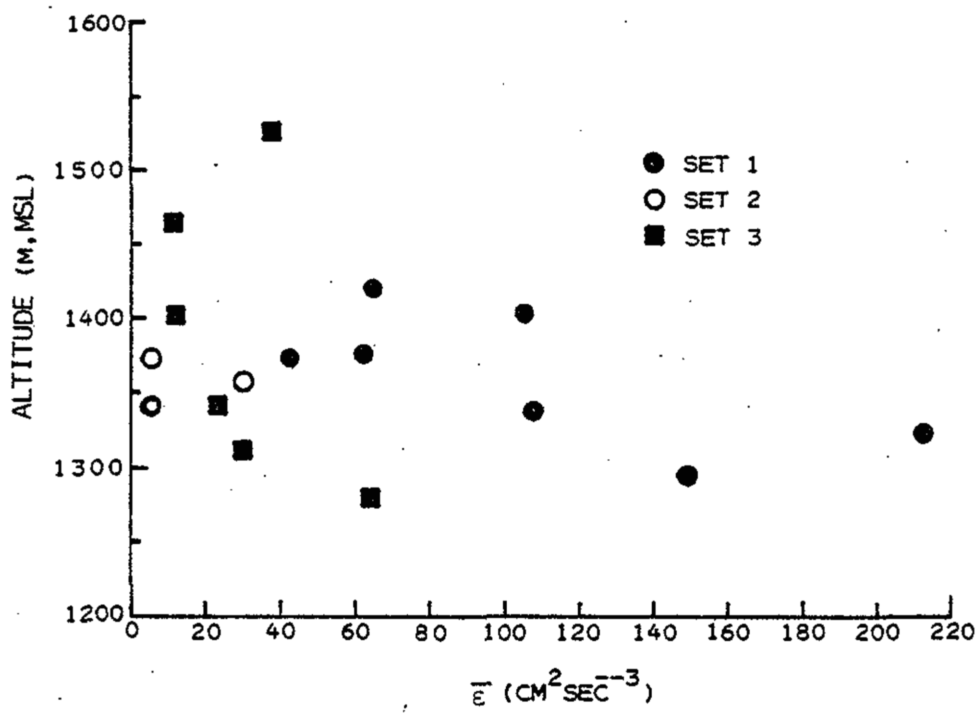


Figure 4.1-24 Turbulence measurements vs. altitude, Test 1.

conditions. Intermittent values were very high during set 1 and appear to reflect discrete turbulence regimes above and below about 1350 m MSL. Values from sets 2 and 3 were typical for the low values of $\bar{\epsilon}$ measured.

4.1.9 Summary of Test 1. The transport pattern of this stable plume was complex. The plume was released during the transition from down-valley to up-valley flow characterized by moderately stable conditions with light and variable winds and experienced initially a large degree of horizontal spreading with little vertical mixing. During the first portion of the release the smoke moved westward while expanding in a north-south orientation. The northernmost extension of the plume continued to move down the Lower Hat Creek Valley and dissipated. The portion of the plume south of the valley junction spread southward in a line extending across the valley, with the eastern portion of the plume visibly denser than the portion to the west. The plume appeared to remain level as it approached rising terrain.

These observations, combined with data from aerial and ground-level sampling, indicate a sequence of events as follows. The plume was released during the transition period from down-valley to up-valley flow. A small portion of the plume was transported down Lower Hat Creek. This portion of the plume evidently fumigated and moved back up-valley, accounting for the presence of SF_6 in ground level samples taken in the lower valley. The bulk of the plume spread westward and gradually sank in response to early heating on the east facing ridges on the west side of the valley. As heating continued general up-valley flow began and the plume moved southward.

There is good evidence that the westernmost extension of the plume began to fumigate at about this time. Aerial measurements of oil fog indicated that measurable concentrations were found further west with decreasing height during cross-valley transects, though the maximum concentrations were found in the elevated layer over the center of the valley which apparently was still stable. Visual observations also indicate that the eastern portion of the plume was denser than that to the west, suggesting greater vertical mixing to the west. SF_6 measurements made near the ground along the eastern slopes showed no measurable concentrations, though oil fog tracking showed rather high concentrations aloft. The surface network indicated higher concentrations as one proceeded south and west, though the plume was visibly fainter here.

It appears that the flow in the lower portion of the mixing layer was from the northeast during fumigation, as the data from weather station 5 indicate (see Volume II, Section 3). Assuming this flow was general across most of the valley, it may be supposed that as the dense, elevated portion of the plume over the east side of the valley was dispersed into the mixing layer, the tracer materials were carried southward and westward causing the maximum ground-level concentrations to be found some distance from the apparent plume centerline.

Though this plume was initially quite stable in appearance, the aerial oil-fog data indicate normalized centerline concentrations associated with Class C stability. The large degree of flow meander during the test was apparently responsible for the observed increase in dilution. Measurements of turbulence dissipation rates showed some very high values in the plume layer over the valley initially and lower values, indicative of stable conditions, in later measurements.

In summary, this test demonstrated that under the conditions experienced, the plume from a 183 m stack at the valley site will be entrained in the valley circulation, gradually sink; and eventually fumigate up-valley from the plant site. The average concentration measured between 1205 and 1305 PST at site 156 indicates that one hour ground level concentrations may be expected to reach at least 2663 $\mu g m^{-3}$.

4.2 Test Number Two, February 20, 1976

This test was conducted from the lower plant site. The meteorological conditions of moderate southerly winds and slightly stable lapse rates were conducive to studying possible plume impact on nearby elevated terrain. A stack height of 183 m was assumed.

4.2.1 Synoptic Setting for Test 2. The surface and 700-mb charts for 0400 PST, February 20, are shown in Figure 4.2-1. Ridging at the surface and aloft can be seen over the area as a trough approached from the west. Winds aloft were stronger than the previous day and were predominantly from the west to northwest. Skies were partly cloudy at the test site with some low and middle level clouds.

4.2.2 Meteorological Parameters for Test 2. Meteorological parameters measured in the test area during the second test consisted of temperature and winds at the surface and aloft. Temperature aloft was measured using minisondes and the NAWC airborne data-acquisition system. Winds aloft were measured by simultaneously tracking pilot balloons with two theodolites. Surface winds were measured by the B. C. Hydro wind monitoring network.

The temperature soundings taken during Test 2 generally showed an inversion layer below about 1300 m MSL with an adiabatic layer above. The inversion layer was weakened with time by surface heating, but a small inversion layer remained until after 1000 PST. The tracer plume was disseminated into the adiabatic layer about 200 m above the top of the inversion. The temperature profiles measured during Test 2 are presented in Figures 4.2-2, 4.2-3, and 4.2-4.

Surface wind data for Test 2 are given in Volume II Field Data. It can be seen that the surface winds during the test were

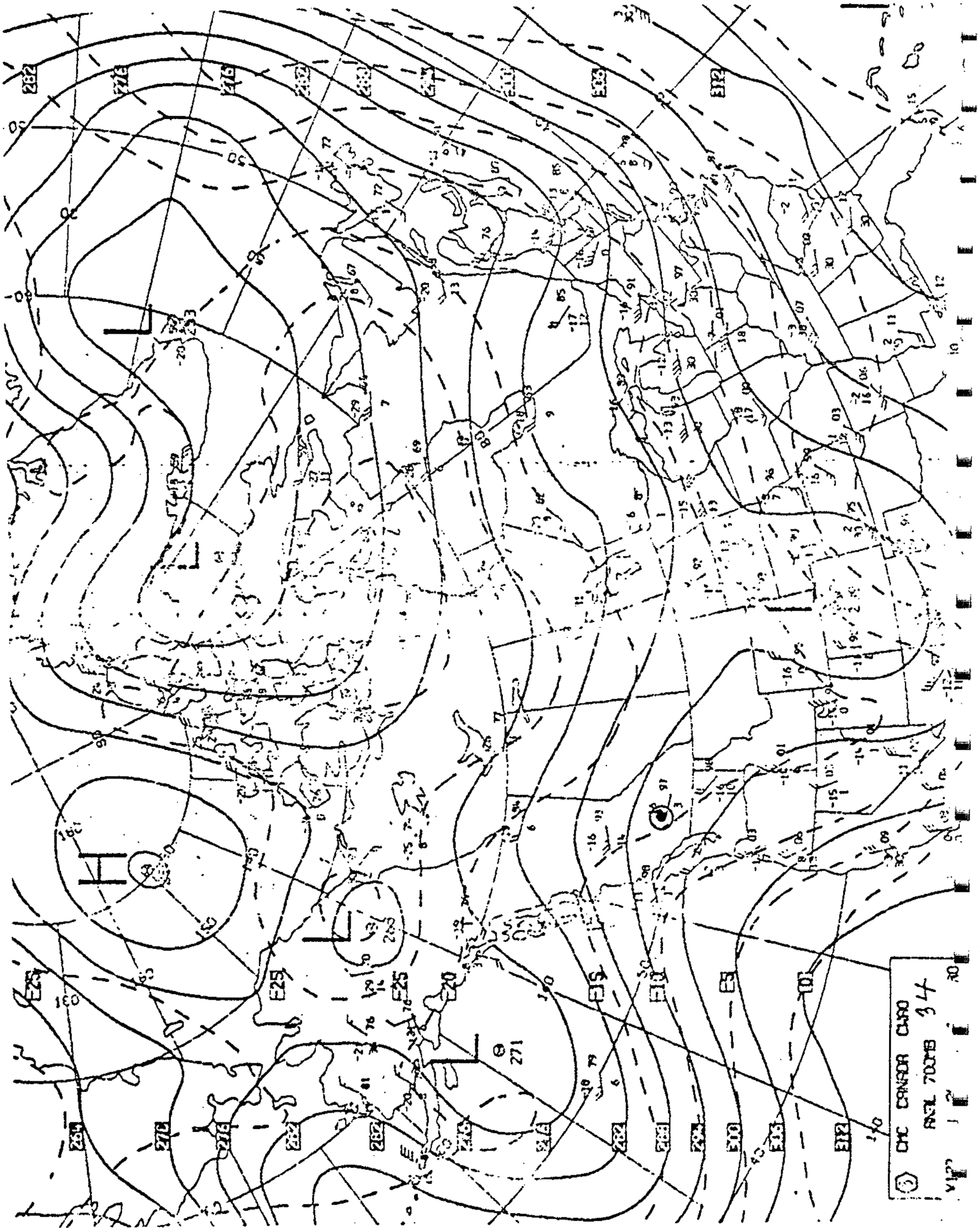


Figure 4.2-1 Surface and 700 mb maps for Test 2, February 20, 1976.

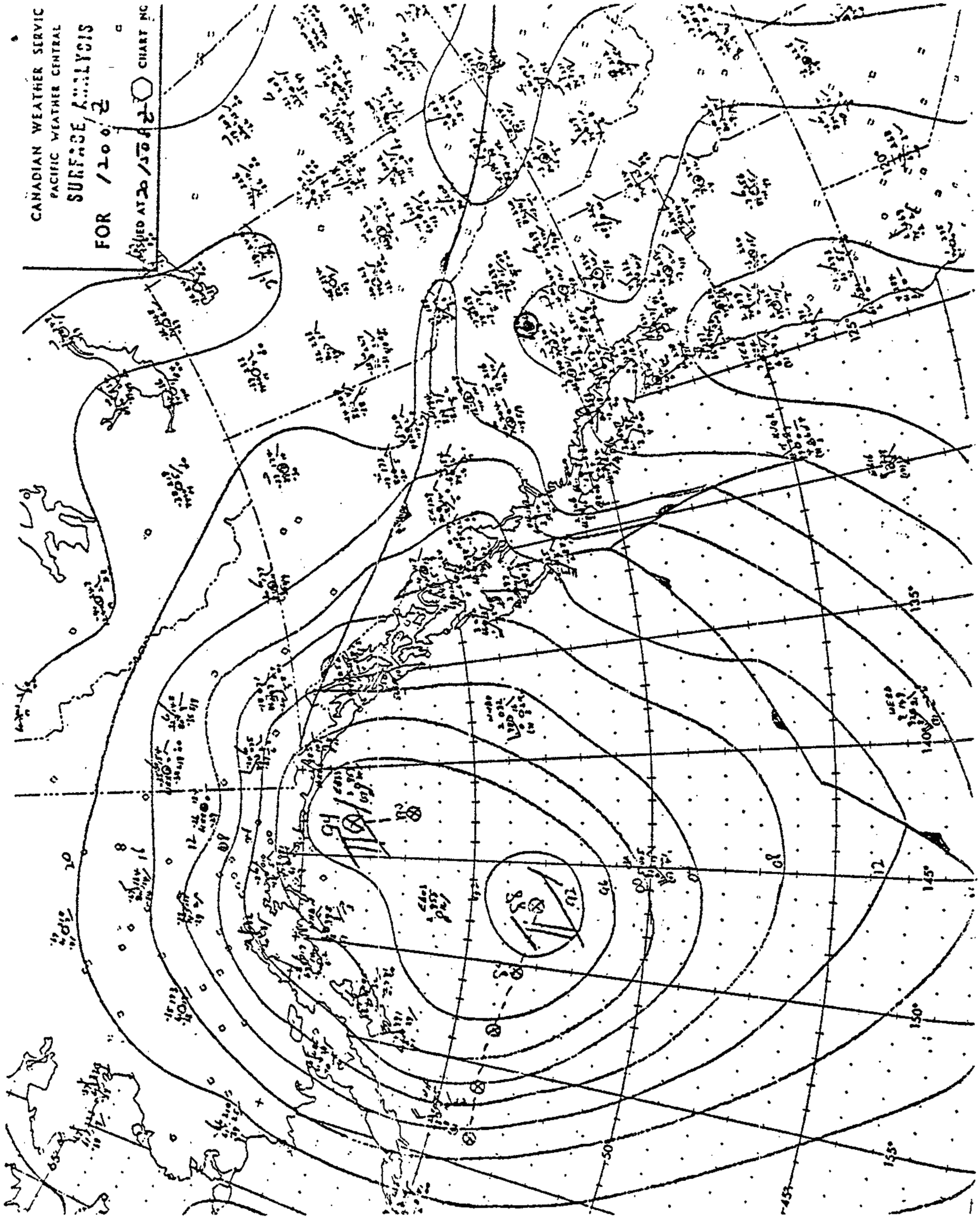


Figure 4.2-1 (Cont'd)

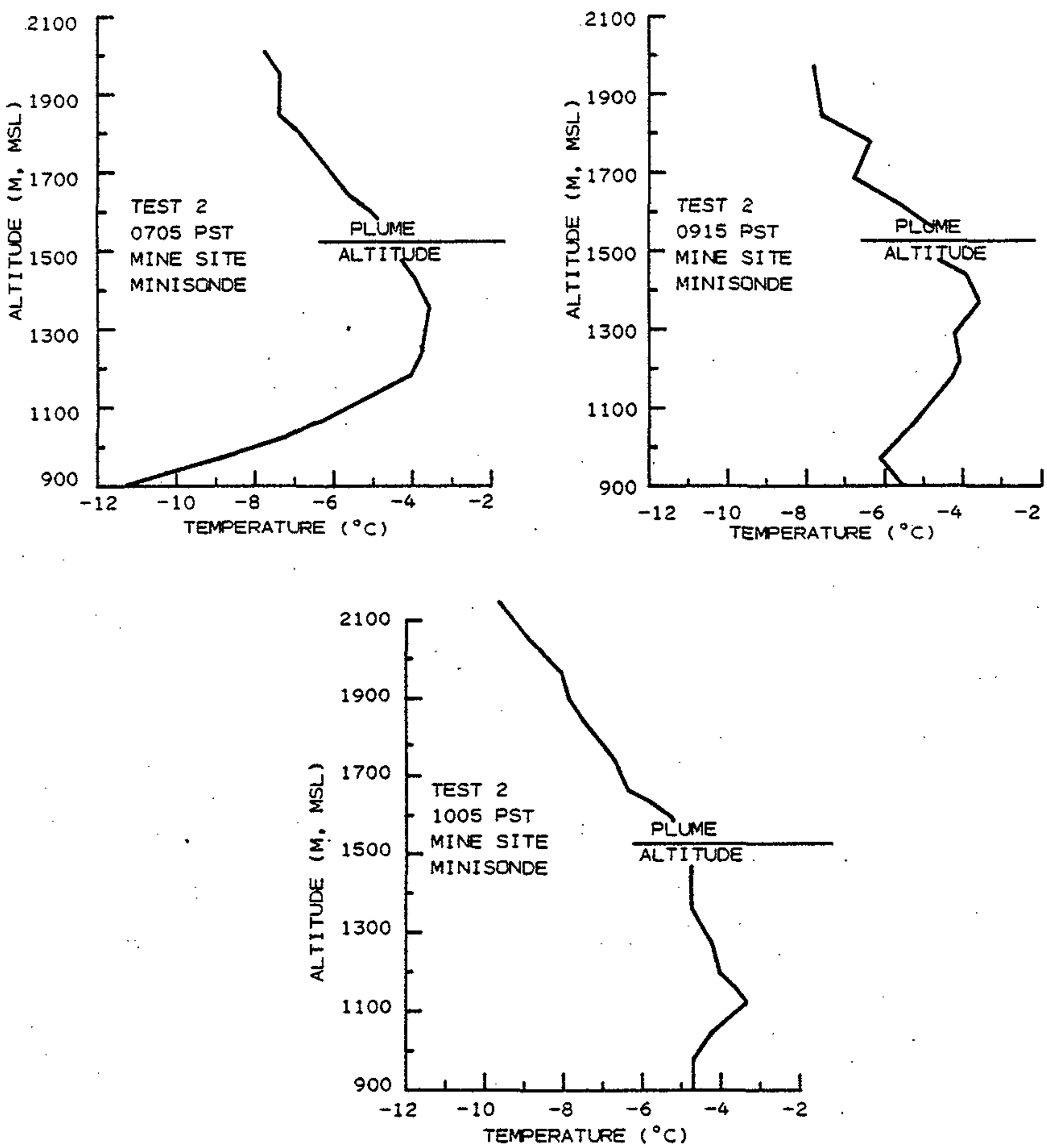


Figure 4.2-2 Vertical temperature profiles measured using minisondes during Test 2.

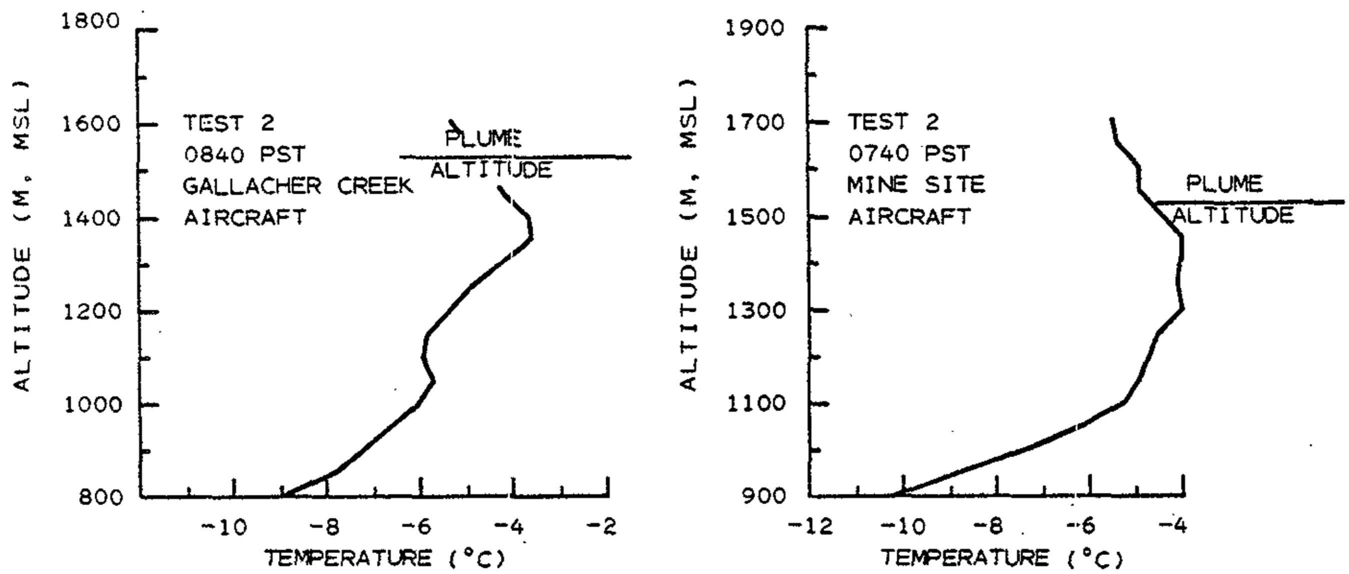


Figure 4.2-3 Vertical temperature profiles measured by the NAWC aircraft system during Test 2. Gallagher Creek is 9 km northeast of the source location.

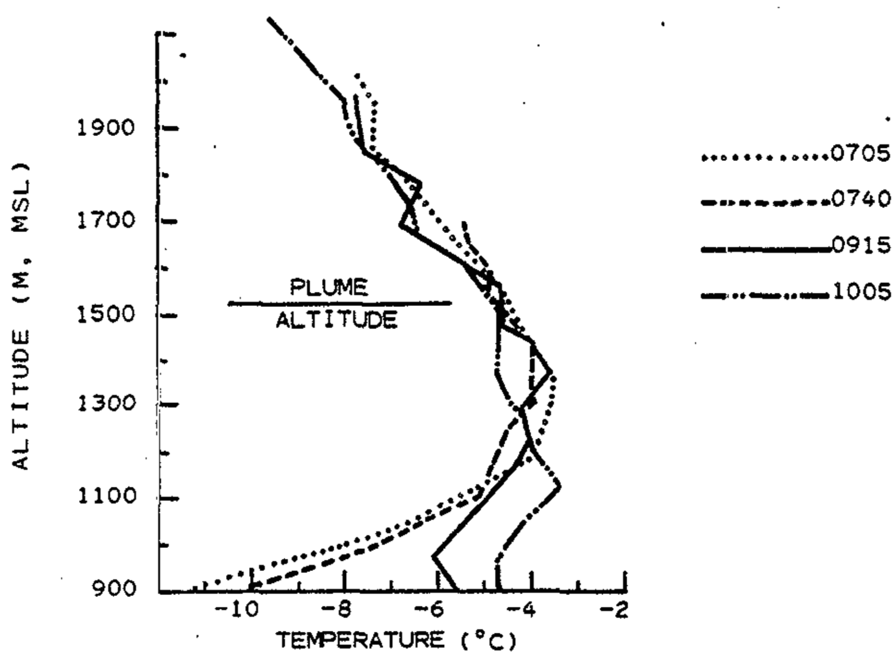


Figure 4.2-4 Superimposed Test 2 temperature profiles measured at the mine site.

light and the flow was generally down-valley. The transition to up-canyon flow took place between 1000 and 1400 at the four low-lying sites, well after the tracer plume was dispensed. The wind data suggest that the diurnal flow pattern in the valley was modified to a certain extent by the southerly flow aloft.

Measurements of winds aloft during the test showed south to south-southwest winds with speeds generally greater than 5 m/s. During much of the dissemination, the winds at plume altitude were from the south at 5 to 6 m/s. Toward the end of dissemination the winds shifted to the south-southwest and increased to over 6 m/s. After dissemination the winds were from the south-southwest at speeds to greater than 7 m/s. Other features in the winds aloft patterns included strong speed shear zones at about 1300 to 1400 m MSL and near 2000 m MSL. The light winds near the surface were variable in direction, while the strong winds above were westerly. The winds aloft measurements are presented in Figures 4.2-5 and 4.2-6.

4.2.3 Tracer Dissemination. Tracer dissemination parameters for Test 2 are shown in Table 4.2-1 below.

Table 4.2-1 Duration and source strength of tracer release number 2.

Location: Valley Site
Altitude: 1525 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	07:48:30	08:48:30	16,798	4.67
Oil Fog (1)	07:48:30	08:20:40	109,800	56.7
Oil Fog (2)	08:33:00	08:48:30	N/A	N/A

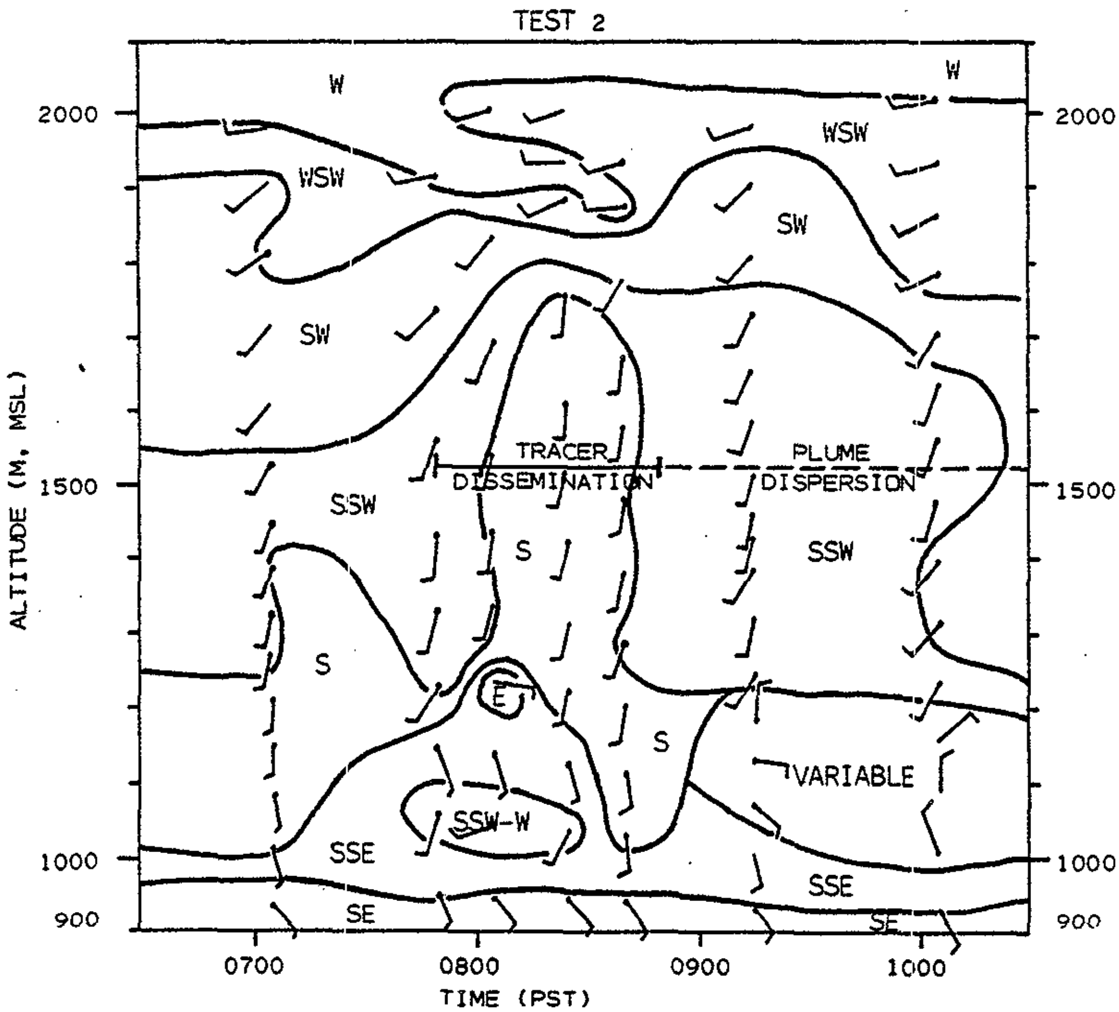


Figure 4.2-5 A time versus altitude display of wind direction aloft measured during Test 2. Barbs indicate wind direction only.

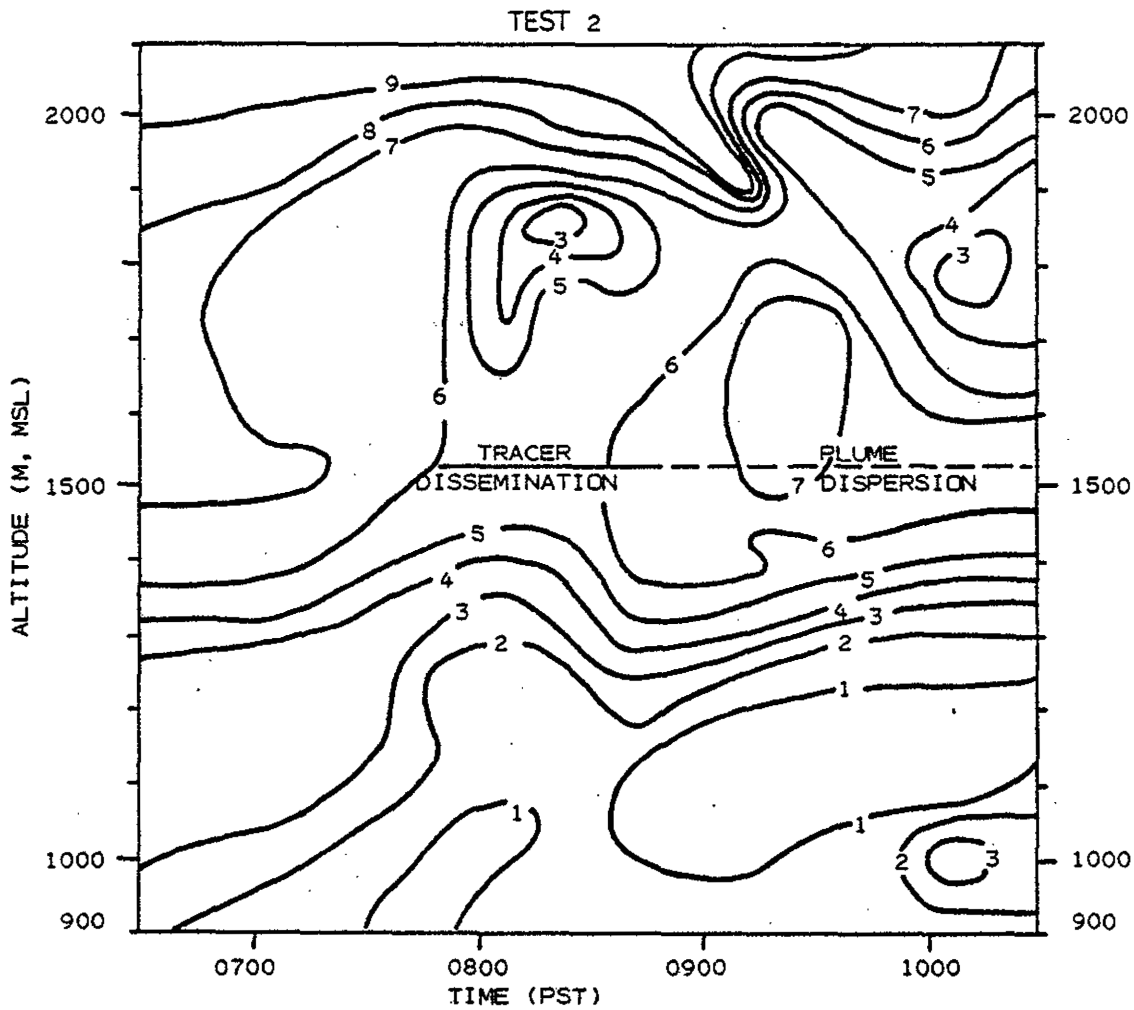


Figure 4.2-6 A time versus altitude display of wind speeds aloft measured during Test 2. Wind speeds are given in m/s.

4.2.4 <u>Visual and Photographic Observation of the Oil-Fog Tracer for Test 2</u>. The transport of the Test 2 oil-fog plume was generally down the south side of the Lower Hat Creek Valley, and it remained quite constant throughout the test. The plume boundaries at various times during the tests are shown in Figure 4.2-7. The transport near the source was toward the east-northeast. As the plume entered the narrower Lower Hat Creek Valley, the trajectory veered to the northeast and followed the south side of the valley (see Figure 4.2-8). The plume was confined generally to the south half of the valley and was faintly visible as far as 11 km down the valley.

The dispersion of the plume could best be described as slightly stable. The plume dispersed to near the terrain on the south side, but over the center of the valley a definite lower limit to the visible plume persisted (see Figure 4.2-9). There was also a discontinuity of dispersion about 2.5 km downwind from the source where the Hat Creek Valley narrows (see Figure 4.2-10. Upwind from that point the rate of dispersion appeared to be less than it was downwind from that point.

4.2.5 <u>Aerial Oil-Fog Measurements</u>. Aerial oil-fog measurements for Test 2 consisted primarily of measurements made during a comprehensive set of crosswind passes made approximately 3.3 km downwind of the release over Lower Hat Creek Valley, as shown in Figure 4.2-11. A second set of measurements is available from a sounding taken over lower Gallagher Creek. The maximum measured oil-fog concentration during Test 2 was equivalent to 3380 μgm^{-3}. This measurement was made during the crosswind pattern at an altitude of 1555 m MSL.

The crosswind passes were made between 0755 and 0830 PST. Thirteen individual passes were made at altitudes between 1370 and 1830 m MSL. Figure 4.2-12 displays the maximum concentrations vs.

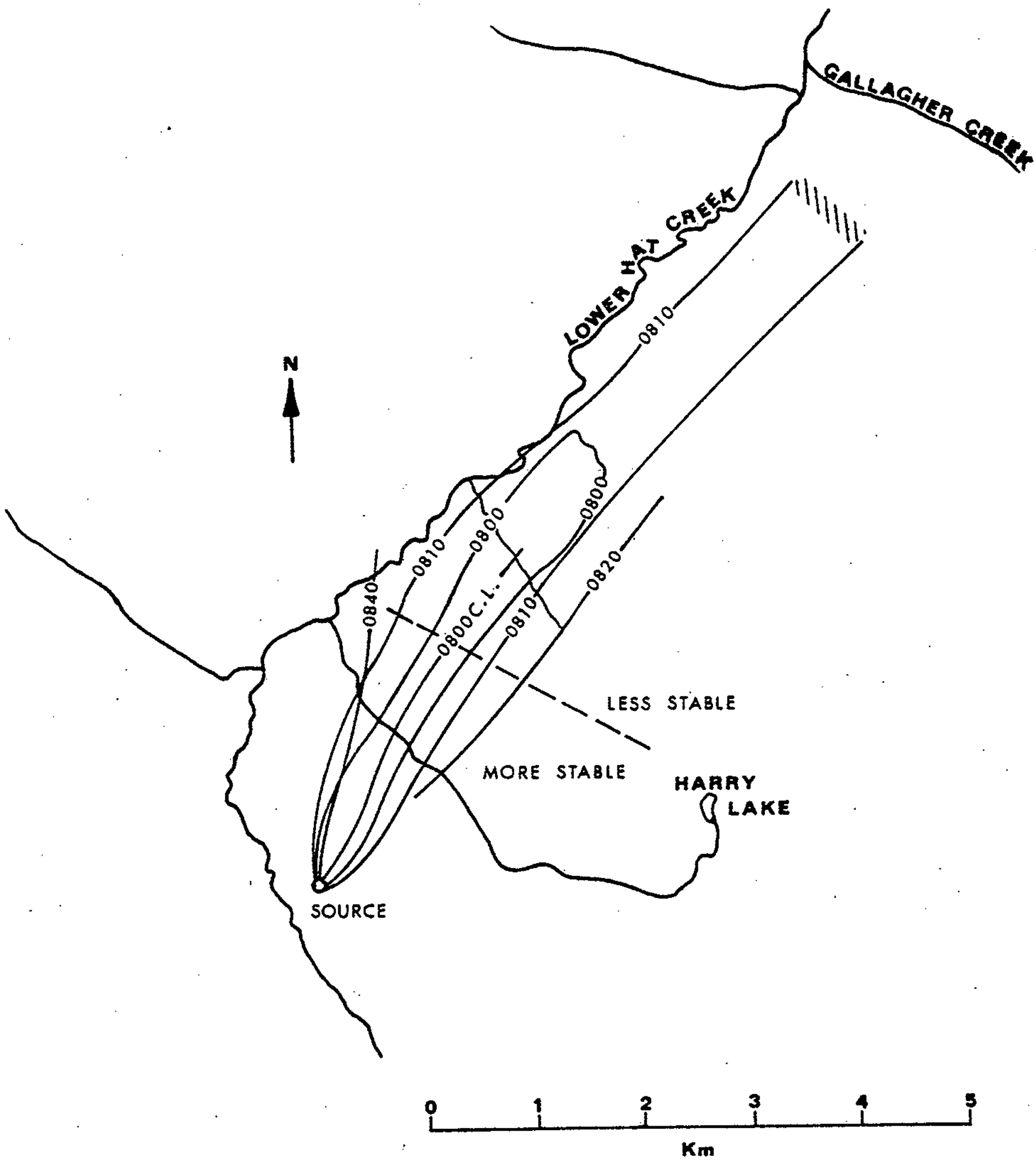


Figure 4.2-7. Plume boundaries at various times during Test 2.

Fig. 4.2-8 A photograph of the Test 2 oil-fog plume taken at 0838 PST. The view is toward the east-northeast.

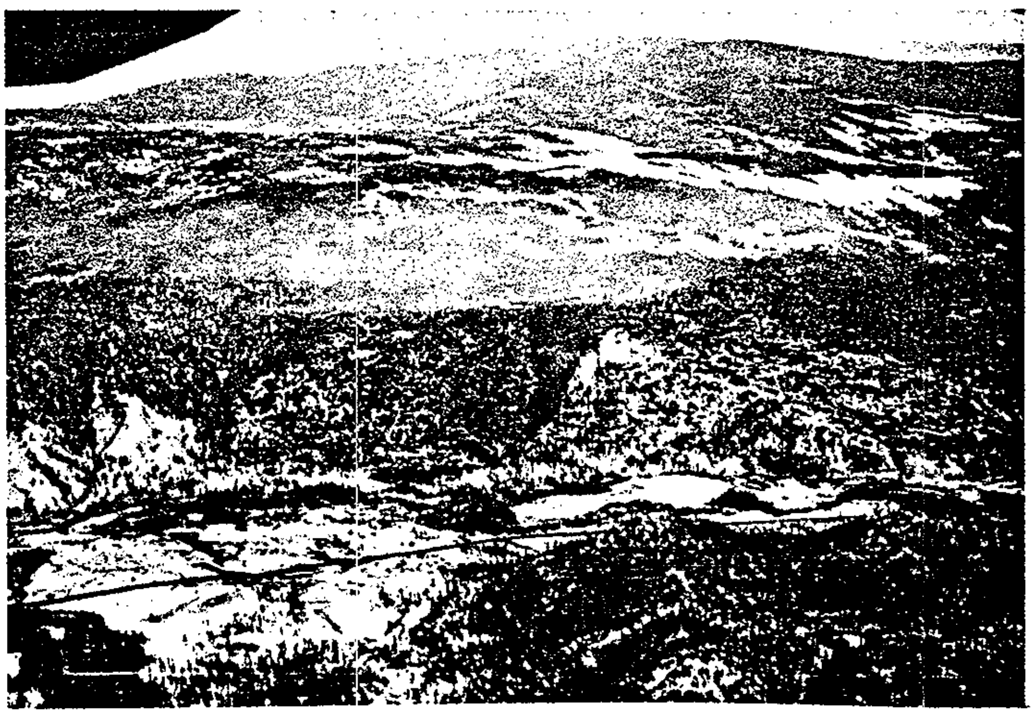


Fig. 4.2-9 A photograph of the Test 2 oil-fog plume taken at 0833 PST. The view is toward the southeast across the Lower Hat Creek valley.

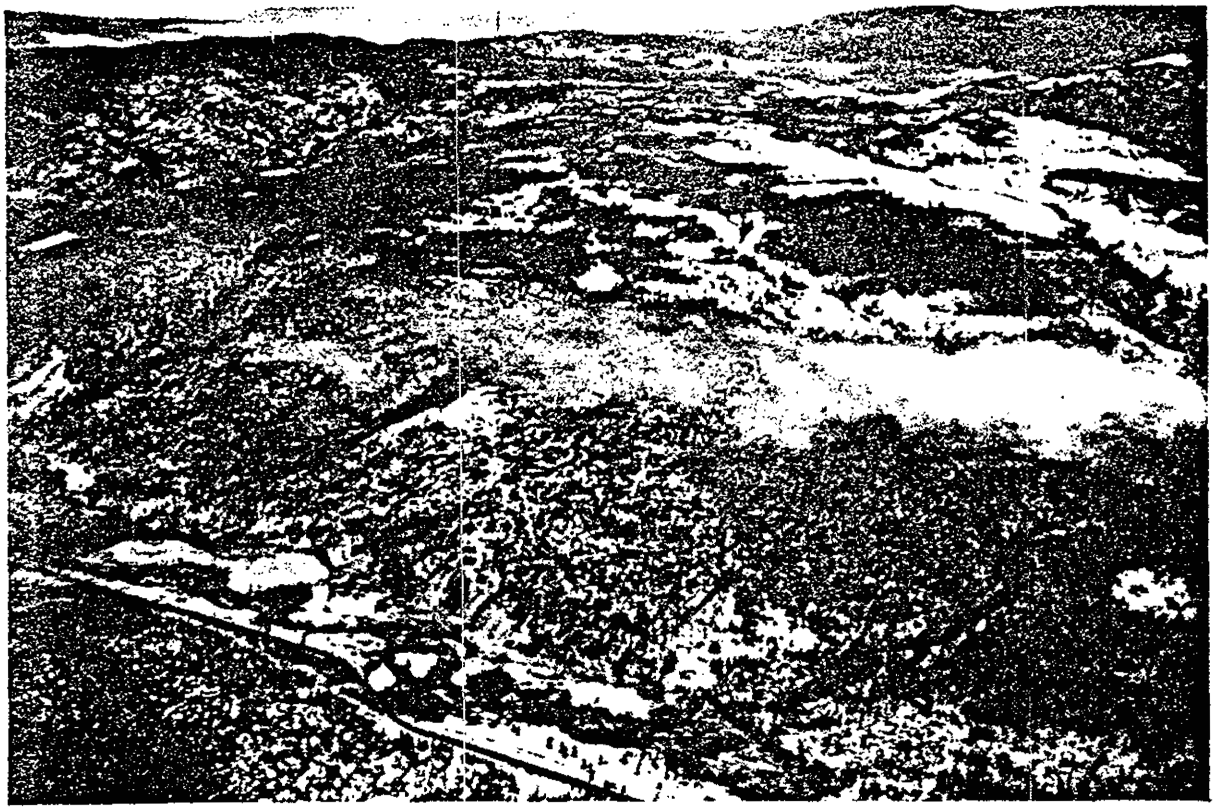


Fig. 4.2-10 A photograph of the Test 2 oil-fog plume taken at 0816 PST. The view is toward the east-southeast.

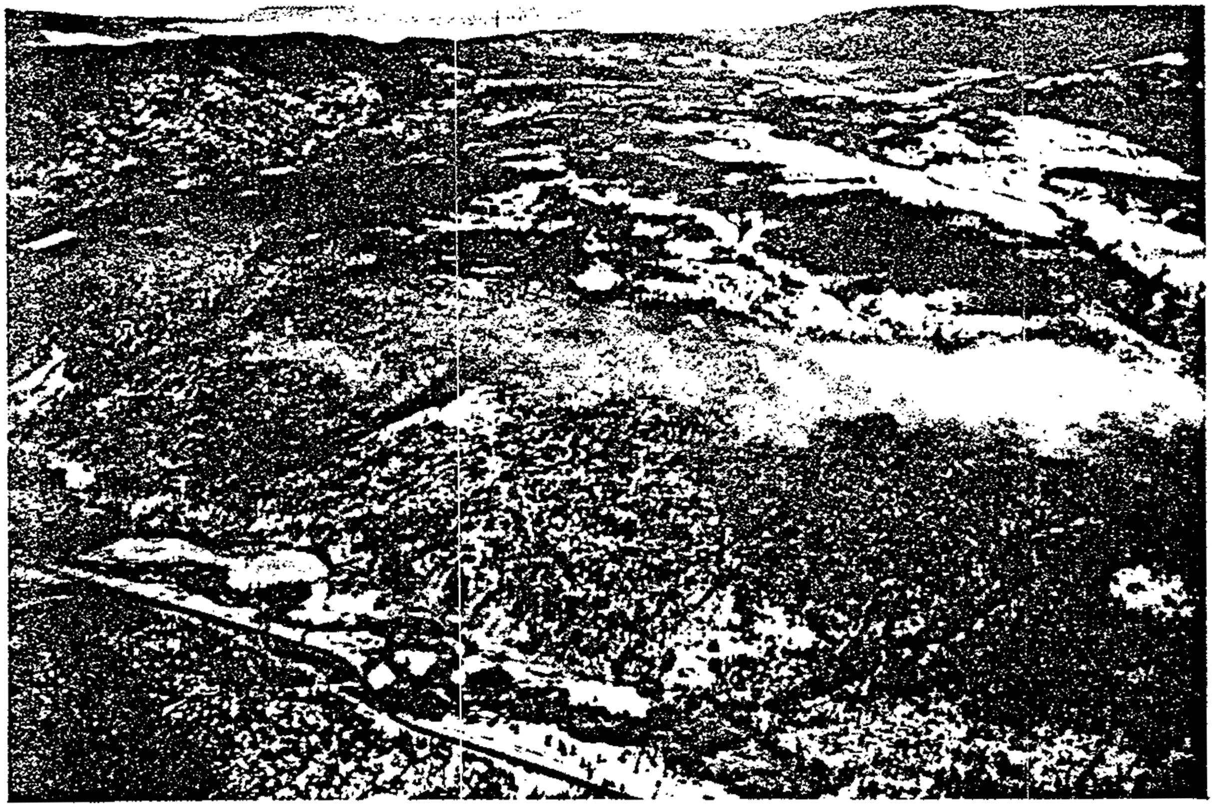


Fig. 4.2-10 A photograph of the Test 2 oil-fog plume taken at 0816 PST. The view is toward the east-southeast.

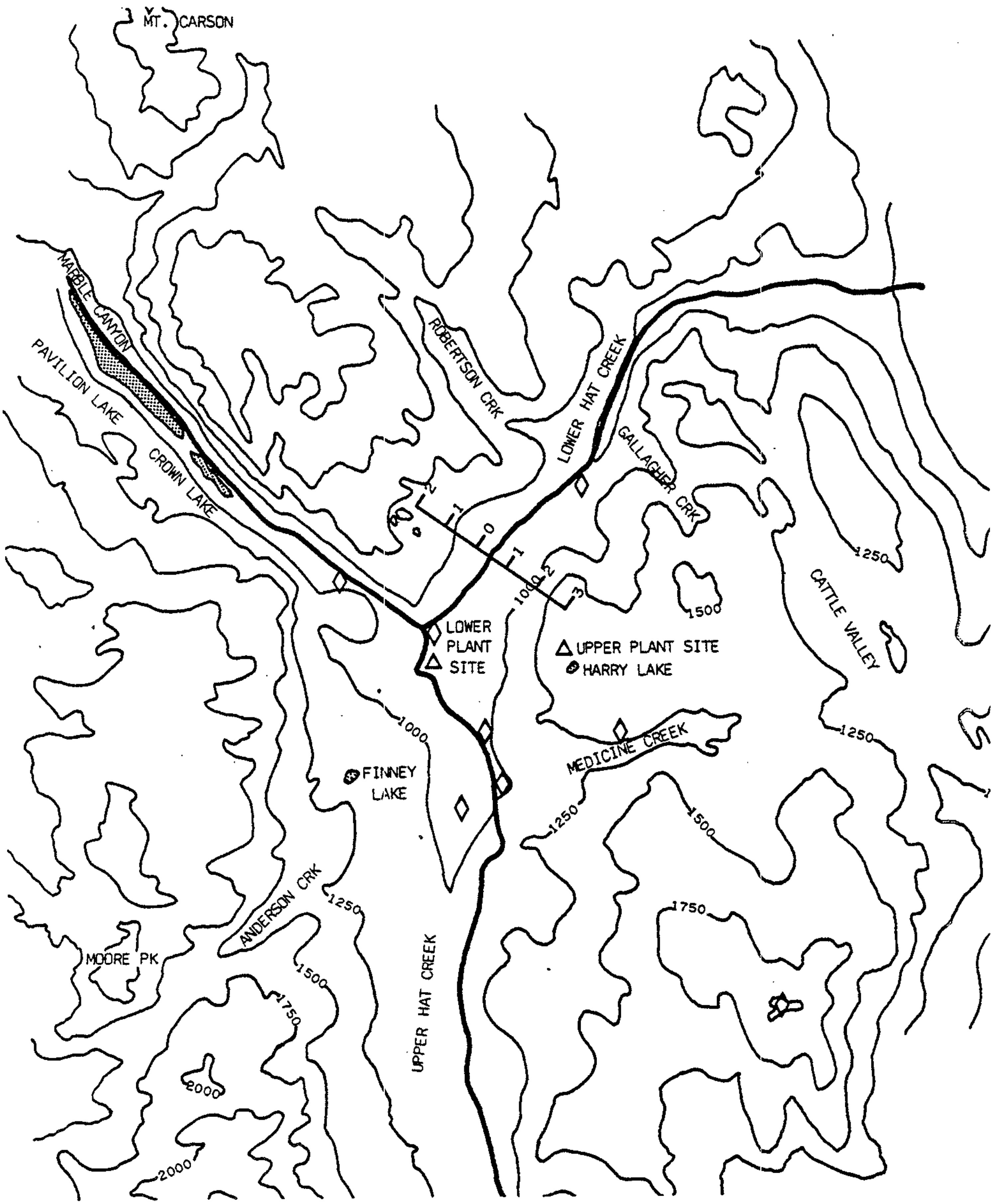


Figure 4.2-11 Location of oil-fog crosswind patterns, Test 2. Distances are in kilometers.

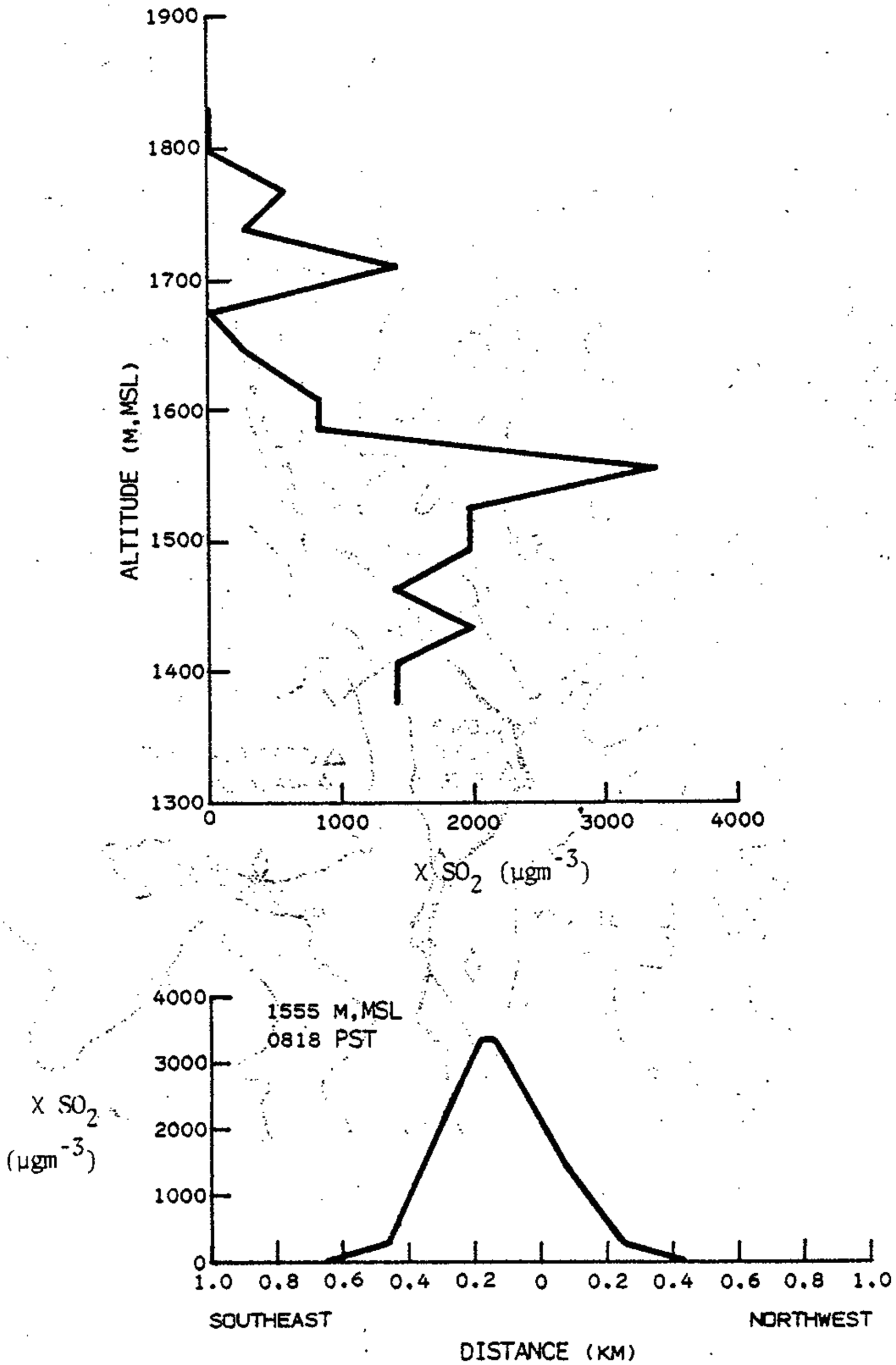


Figure 4.2-12 Horizontal and vertical plume centerline distributions, Test 2.

altitude and also the distance vs. concentration plot for the pass at 1555 m MSL. The values of σ_y and σ_z for this location have been computed and are shown along with the standard curves in Figure 4.2-13. It can be seen that both measurements fall near the nominal values for D-E stability. The value of $\frac{\chi \bar{u}}{Q}$ has been plotted in Figure 4.2-14 and indicates a rate of dilution approximately twice that shown for D stability over flat terrain.

The oil-fog data show that the plume centerline was near the center of the valley above 1525 m MSL but shifted southward below. Concurrently, the southern boundary of the plume shifted southward with decreasing altitude. These observations suggest that under the prevailing south-southwest flow aloft (see Figure 4.2-5) the effect of terrain channeling was to transport the lower portions of the plume in a northeasterly direction (that is, following the lay of Lower Hat Creek), while the elevated portion moved more in the direction of the gradient flow. The point at which there appeared to be an abrupt change in the rate of diffusion (see Figure 4.2-7) may reflect the increased shear between the surface flow and the flow aloft where the orientation of Hat Creek changes.

A secondary set of oil-fog measurements were gathered during a vertical temperature sounding taken over Lower Gallagher Creek between 0836 and 0842 PST. These measurements showed a peak concentration of 845 μgm^{-3} between 1330 and 1370 m MSL. Though threshold concentrations of 282 μgm^{-3} were found as high as 1620 m MSL and as low as 40 m AGL (810 m MSL), the bulk of the plume was found between 1170 and 1430 m MSL. This represents about 175 meters of sinking of the plume layer since the release. Apparently, this is related to the terrain of Hat Creek which falls 145 m between the release point and the location of this measurement.

The values of σ_z and $\frac{\chi \bar{u}}{Q}$ for this set of measurements are plotted in Figures 4.2-13 and 4.2-14. It can be seen that these

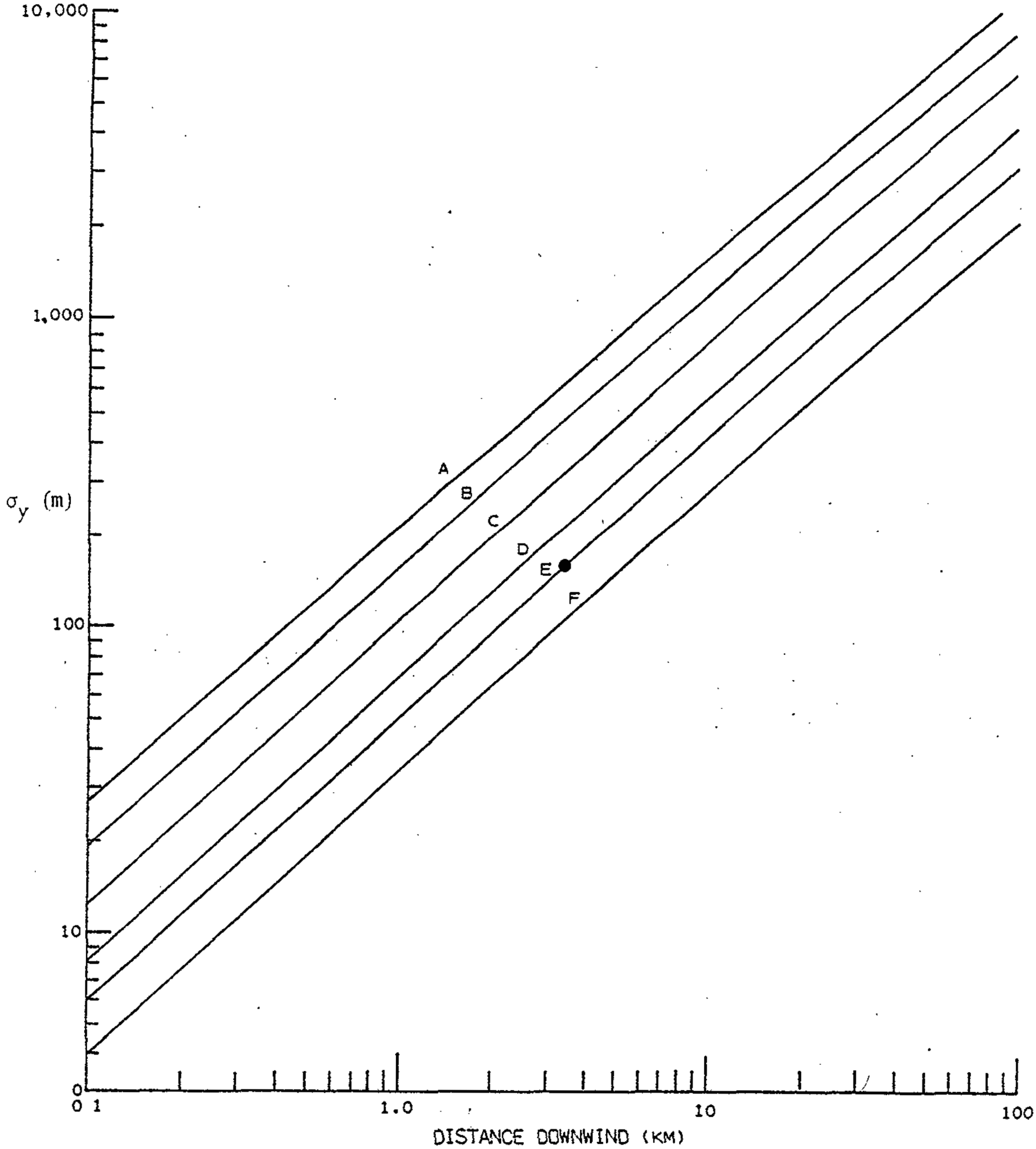


Figure 4.2-13 Measured values of σ_y and σ_z for Test 2.

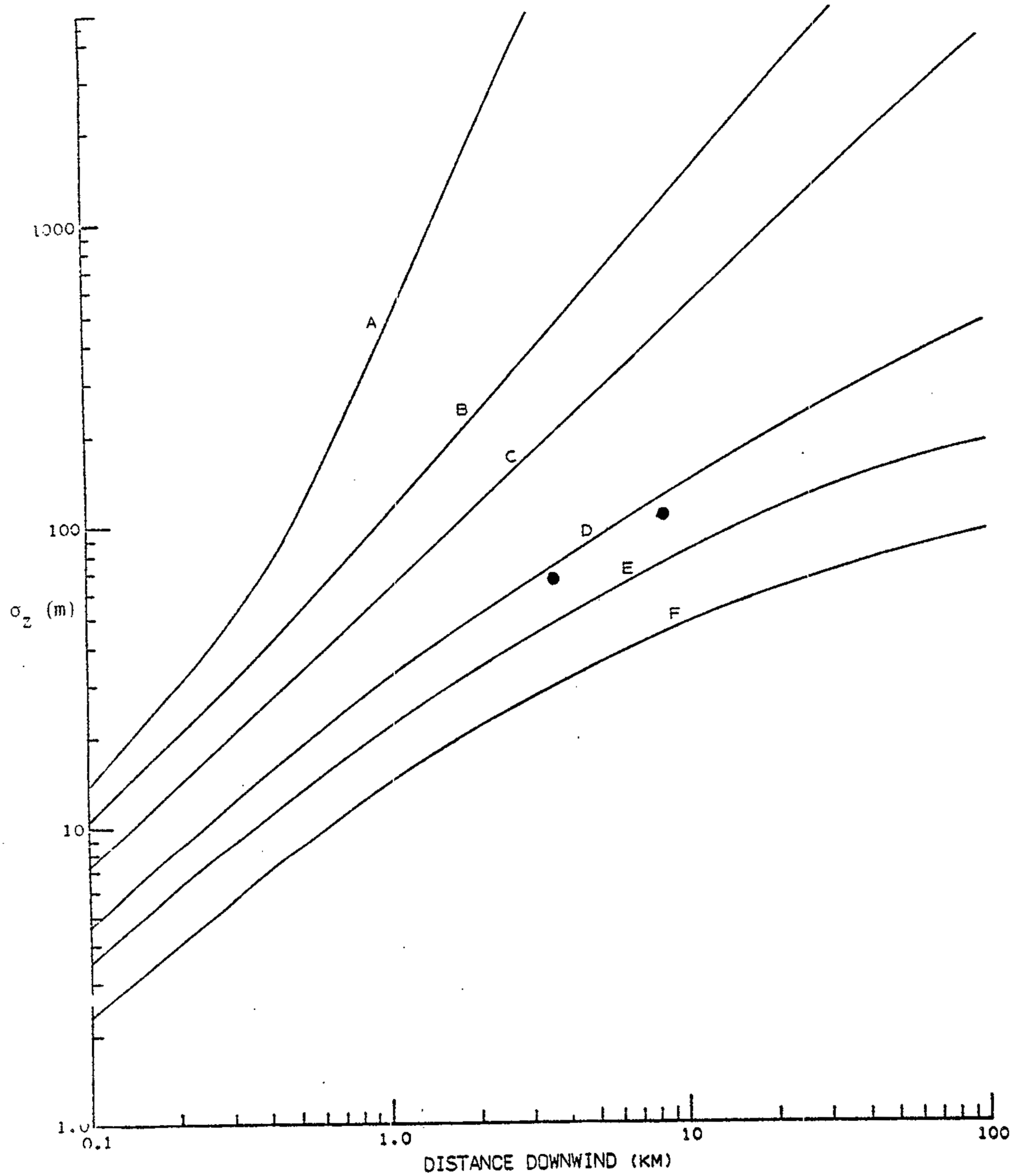


Figure 4.2-13 (Cont'd)

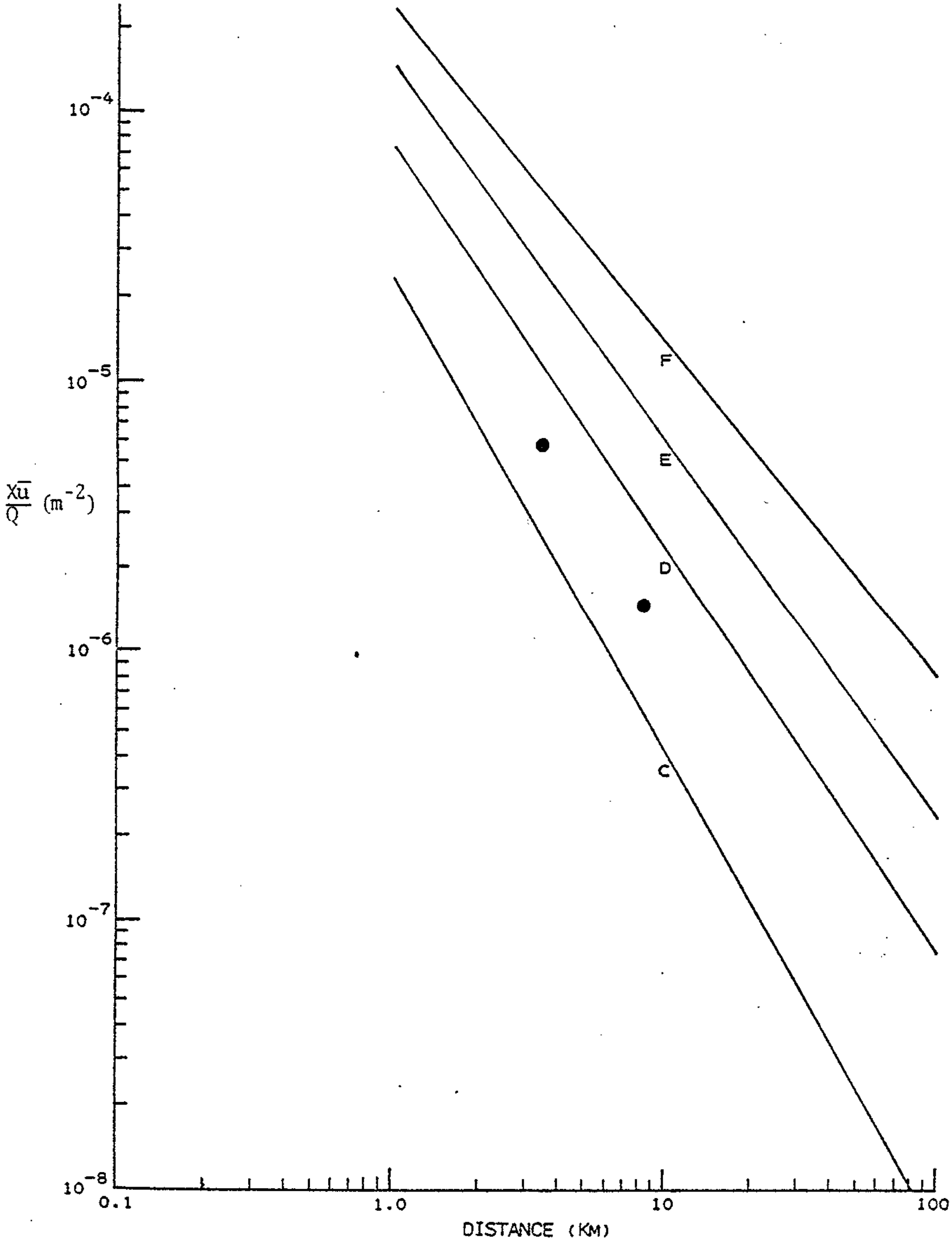


Figure 4.2-14 Measured values of $\frac{\chi \bar{u}}{Q}$ for Test 2.

values tended to agree rather well with the predicted curves for D stability. A value has also been plotted for a peak aerial SF_6 measurement taken at Gallagher Creek. This has been included as it was somewhat higher than the measured peak oil-fog concentration during the Gallagher Creek sounding.

4.2.6 <u>Aerial SF_6 Measurements</u>. A total of 17 aerial samples was taken during Test 2. Most of these yielded measurable concentrations, though the majority were quite low. The maximum measured concentration was equivalent to 2472 μgm^{-3} SO_2. This concentration was measured near Lower Gallagher Creek, 8.6 km downwind, at an altitude of 1310 m MSL. The locations of aerial samples are shown in Figure 4.2-15. Supplementary information is supplied in Table 4.2-2.

Aerial sampling during Test 2 began with two background samples prior to the release. One showed a very low concentration of SF_6 which perhaps represents residual material from Test 1, the previous day. Between 0808 and 0827 PST, eight samples (numbers 3-10) were taken in a cross-valley pattern across Lower Hat Creek at altitudes of 1495, 1370, and 1190 m MSL. The maximum measured concentration during these crosswind passes was equivalent to 592 μgm^{-3} SO_2 at an altitude of 1370 m MSL. The results of these passes are shown in Figure 4.2-16. Following this, a sample was taken over Gallagher Creek at 1190 m (sample number 11) which yielded 100 μgm^{-3}. Sample 12, taken 4.0 km downwind of the release at an altitude of 1190 m MSL, 335 m below release altitude, had an equivalent concentration of 1432 μgm^{-3}. Sample 13, also taken at 1190 m MSL along the southern hills of Lower Hat Creek, had an equivalent concentration of 394 μgm^{-3}, in good agreement with the previous measurements taken nearby. Samples 14 through 17 were all taken in the vicinity of Gallagher Creek. Here the maximum SF_6 concentration for the test was found at 1310 m MSL on Lower Gallagher Creek. This concentration was equivalent

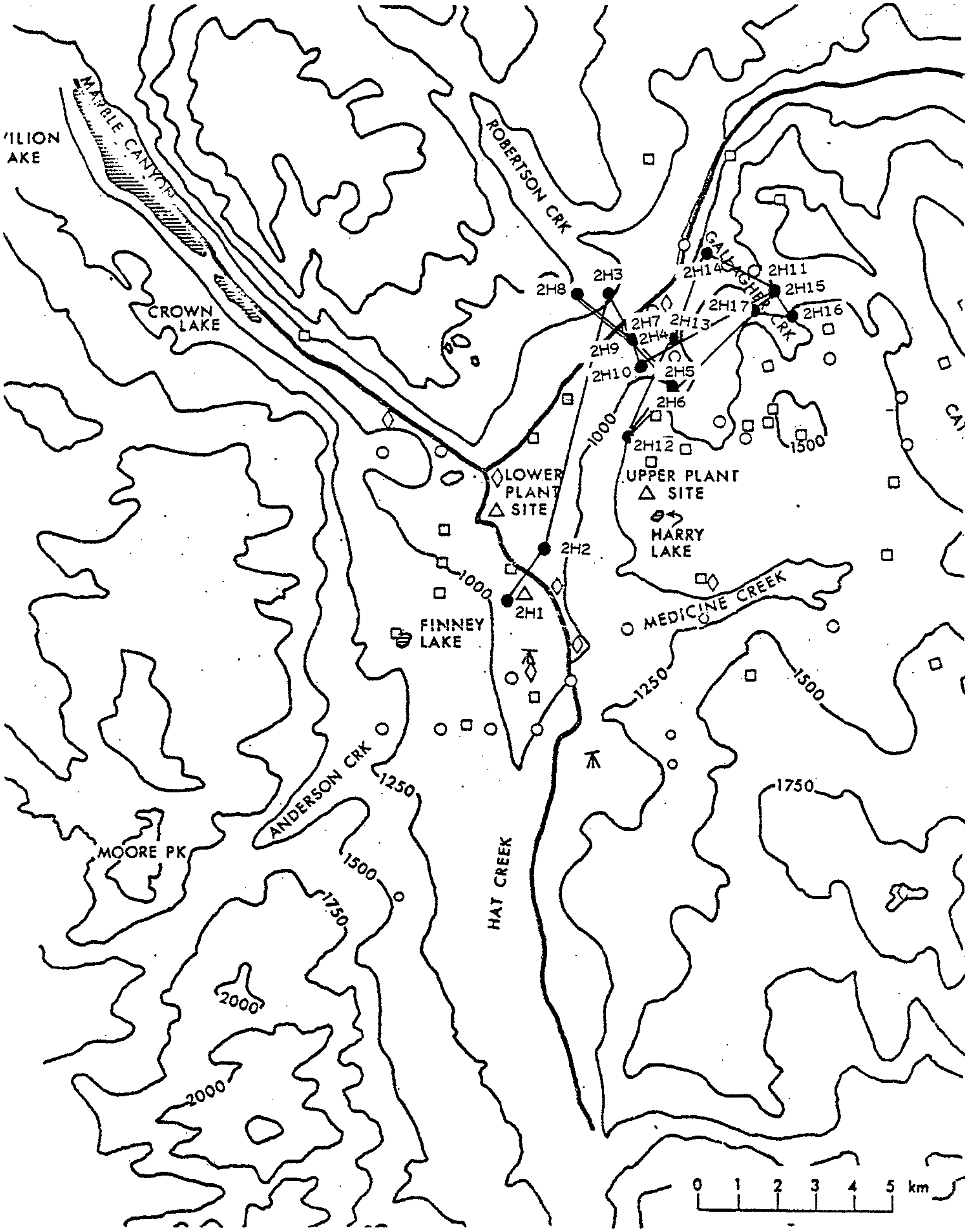


Figure 4.2-15 Locations of aerial SF_6 samples, Test 2.

Table 4.2-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	NTP
2H1	2.4	1190	290	0800	0.25	100	111
2H2	1.6	1190	290	0801	0.25	0	0
2H3	6.3	1495	395	0808	1	100	111
2H4	5.6	1495	695	0810	1	346	382
2H5	5.6	1495	395	0812	1	100	111
2H6	5.6	1370	270	0815	1	592	654
2H7	5.6	1370	570	0817	1	444	491
2H8	5.9	1370	220	0820	1	100	111
2H9	5.6	1190	390	0823	1	296	327
2H10	5.4	1190	290	0826	1	296	327
2H11	9.1	1190	190	0834	1	100	111
2H12	4.0	1190	140	0845	1	1432	1582
2H13	6.4	1190	290	0847	1	394	435
2H14	8.6	1310	525	0852	1	2472	2732
2H15	9.1	1310	310	0855	1	492	544
2H16	9.1	1370	270	0854	1	100	111
2H17	8.5	1370	220	0904	0.25	100	111

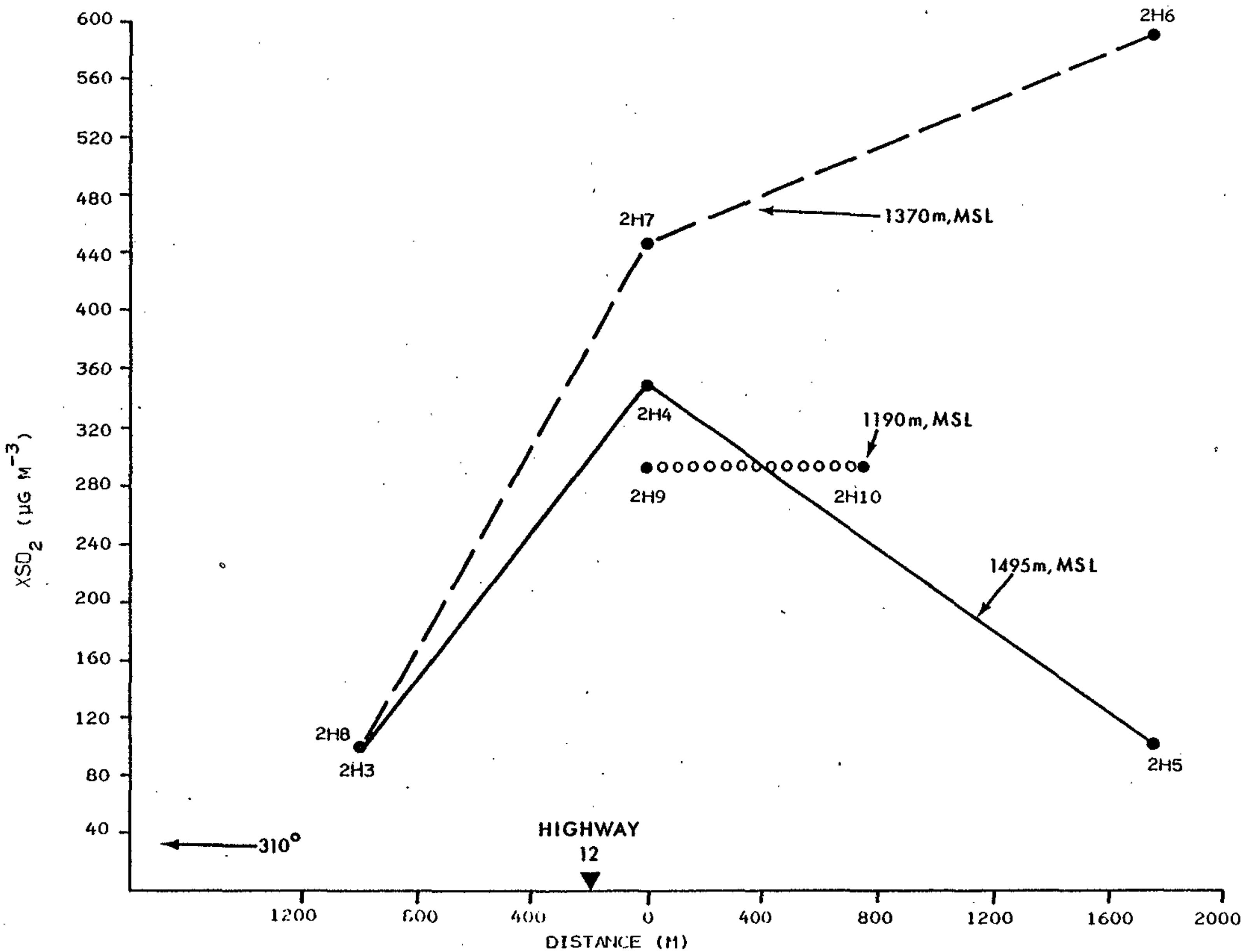


Figure 4.2-16 SF_6 cross-valley concentrations from aerial samples 2H3-2H10.

to 2472 μgm^{-3} SO_2. Samples 15, 16, and 17 were taken in Upper Gallagher Creek at altitudes of 1310, 1370, and 1370 m AGL, respectively. These showed a much higher concentration at 1310 m MSL (492 μgm^{-3}) than at 1370 m (100 μgm^{-3}).

These data support the aerial observer's comment that the plume traveled along the south side of Lower Hat Creek Valley.

4.2.7 Surface SF_6 Measurements. A total of eight ground SF_6 samplers was deployed for Test 2. Their locations are indicated on Figure 4.2-17. Table 4.2-3 gives data concerning sample time, sampler altitudes, and concentrations in μgm^{-3} SO_2. The maximum measured ground concentration for Test 2 was equivalent to 246 μgm^{-3} SO_2 measured over a half hour. This was measured at site 2S4, located 4.8 km downwind from the release, at an altitude of 1280 m MSL, 245 m below the release altitude. Most samplers showed near-threshold values of 50-100 μgm^{-3} at some time during the test. Samplers 2T5 and 2T6, located in the Lower Hat Creek Valley, 3.4 and 2.0 km downwind, respectively, measured 100 μgm^{-3} during the period 0850-1050 PST at 2T6 and 0845-0945 PST at 2T5. Site 2T1, 5.8 km from the release showed a measured concentration of 50 μgm^{-3} during the three-hour period from 0850-1150 PST.

These data suggest that the plume centerline remained well aloft as it passed down Hat Creek towards the northeast and that extensive lateral and vertical mixing limited ground level concentrations to the low levels observed.

4.2.8 Turbulence Measurements. The turbulence measurements from the oil-fog crosswinds are shown in Figure 4.2-18. The values of $\bar{\varepsilon}$ were very high and generally ranged from 75-150. The values of I were slightly higher than might be expected with the extensive mechanical turbulence generated over the rough terrain by the strong winds, perhaps reflecting intermittent disturbances generated by shear.

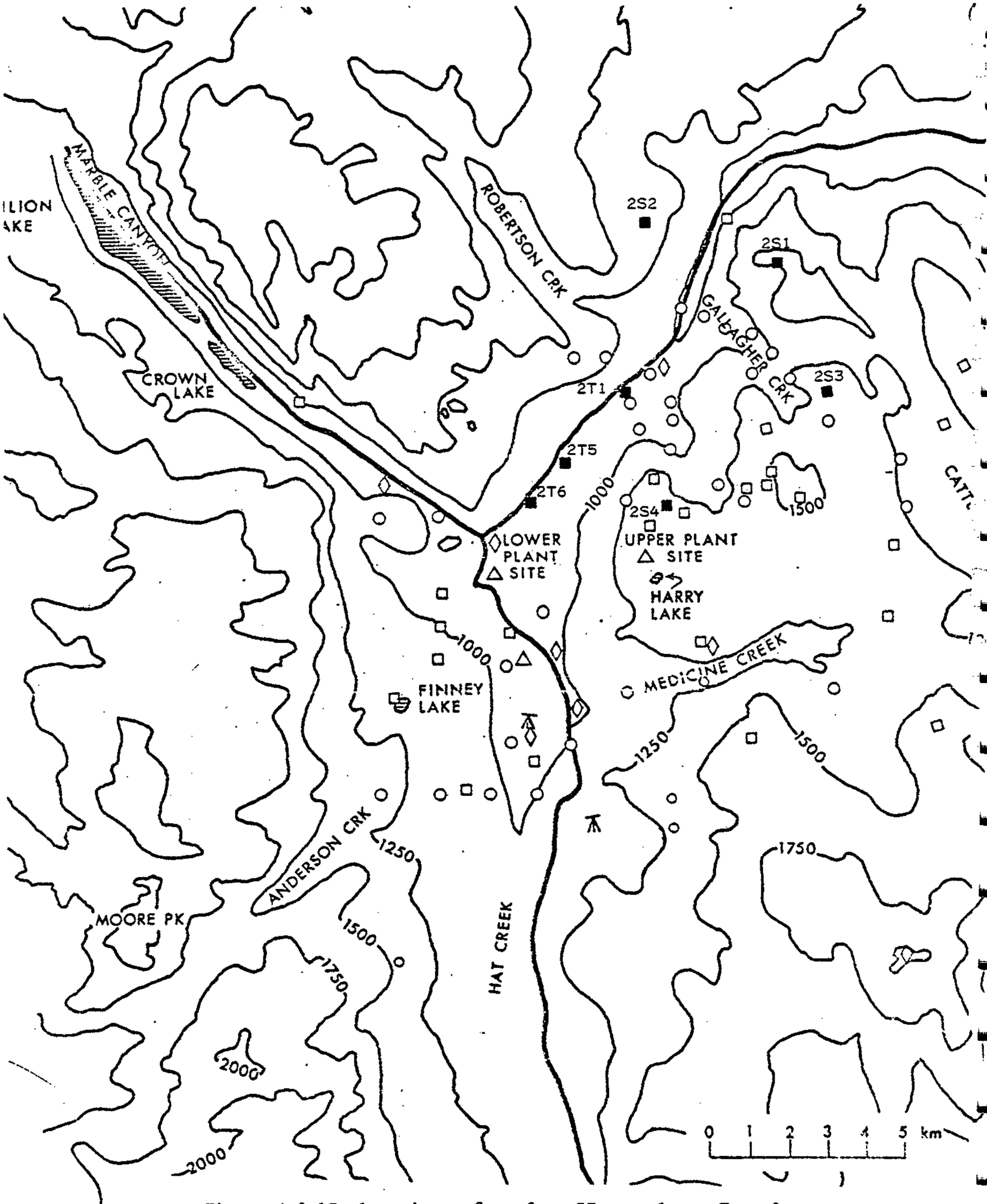
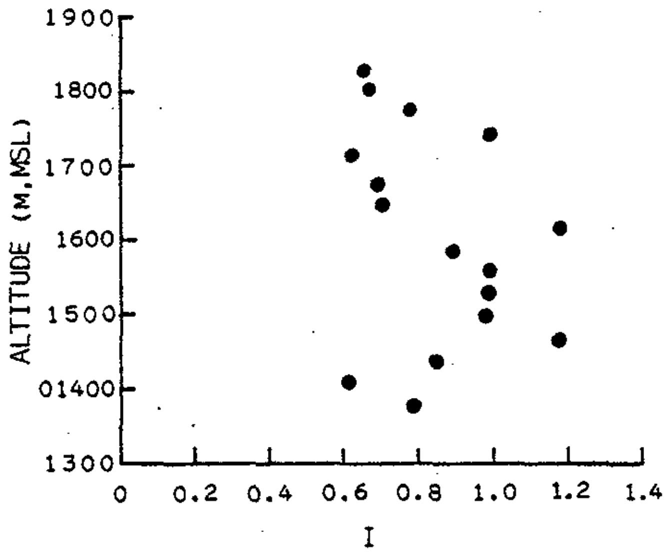


Figure 4.2-17 Locations of surface SF_6 samplers, Test 2.

Table 4.2-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 ($\mu g m^{-3}$)	
						Ambient	NTP
2S1	10.8	1270	0814	0844	30	0	0
			0844	0914	30	146	161
			0914	0944	30	50	55
			0944	1014	30	100	111
			1014	1044	30	0	0
			1044	1105	Malf.	-	-
2S2	10.0	1115	0822	0852	30	0	0
			0852	0922	30	0	0
			0922	0952	30	100	111
			0952	1022	30	0	0
			1022	1052	30	50	55
			1052	1112	20	0	0
2S3	9.8	1370	0832	0902	Malf.	-	-
			0902	0932	30	30	33
			0932	1022	30	0	0
			1002	1032	30	0	0
			1032	1102	Malf.	-	-
			1102	1125	23	0	0
2S4	4.8	1280	0847	0917	30	246	272
			0917	0947	30	196	217
			0947	1017	Malf.	-	-
			1017	1047	Malf.	-	-
			1047	1117	30	100	111
2T1	5.8	775	0850	1150	180	50	55
2T5	3.4	800	0845	0945	60	100	111
			0945	1045	60	30	33
2T6	2	825	0850	0950	60	100	111
			0950	1050	60	100	111



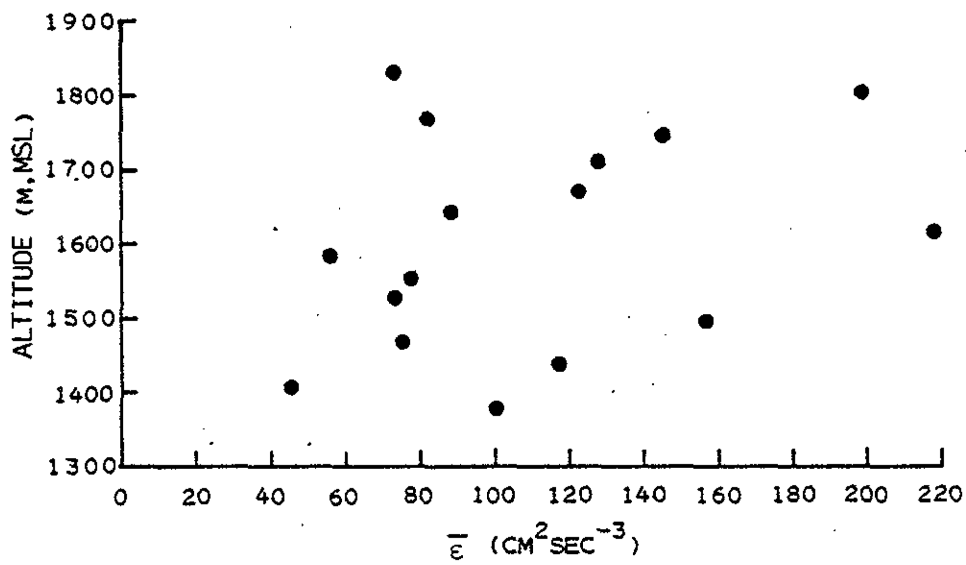


Figure 4.2-18 Turbulence measurements vs. altitude, Test 2.

4.2.9 <u>Summary of Test 2</u>. The second tracer release was made from the valley site into near-neutral conditions with a stable layer below. Winds at plume altitude were from the south-southwest at between 5 and 7 m/s. The plume moved over the northwesternmost extension of the Trachyte Hills, turning gradually to the east in conformance with the terrain of Lower Hat Creek Valley.

Visual observations and aerial oil-fog and SF_6 tracking indicate that most of the plume remained over the southern half of the lower valley as it moved downwind. These data also suggest that while the plume remained aloft over the valley, some surface impact was taking place on the slopes. It seems likely that a stable layer below the plume over the center of the valley prevented downward transport there, while more neutral conditions and enhanced turbulence over the southern slopes allowed ground level impact there.

Normalized centerline concentrations computed from aerial oil-fog and aerial SF_6 data indicate values associated with neutral to slightly stable conditions. Turbulence dissipation rates, as measured during the oil-fog crosswinds, were very high and represent values typical of C stability. The turbulence regime was evidently greatly enhanced by strong shear and extensive mechanical turbulence.

Ground level impact was light, with the maximum measured half-hour and one-hour concentrations being equivalent to 246 and 221 ngm^{-3}, respectively. One-hour concentrations are derived by averaging two sequential half-hour measurements.

4.3 <u>Test Number Three, February 21, 1976</u>

This test was conducted at the upper site. The meteorological conditions of strong winds and slightly stable temperature profiles were conducive to investigating possible plume downwash in the lee of the Trachyte Hills and channeling effects in Lower Hat Creek Valley. A stack height of 183 m was assumed.

4.3.1 Synoptic Setting for Test 3. The surface and 700 mb maps for February 21 are shown in Figure 4.3-1. Both of these show ridging over the project area. Surface gradients were from the south to southwest as a vigorous frontal system approached from the Gulf of Alaska. High overcast persisted over the site during the test.

4.3.2 Meteorological Parameters for Test 3. Meteorological parameters measured in the test area during the third plume simulation consisted of temperature and winds at the surface and aloft. Winds aloft were measured by simultaneously tracking pilot balloons with two theodolites. Surface winds were measured by the B. C. Hydro wind monitoring network. Temperature aloft was measured using minisondes and the NAWC airborne data acquisition system.

The temperature profiles measured at various times on the day of the test are presented in Figures 4.3-2, 4.3-3, and 4.3-4.

Those temperature soundings revealed two inversion layers. One was near the surface in the valley and one aloft. At the mine site the minisondes measured elevated inversions based at about 1600 m MSL, while further east over Harry Lake and the Lower Hat Creek Valley the base of the elevated inversion was measured by the aircraft system at about 1900 m. Based upon the soundings made at the source location by the aircraft system, the plume was disseminated just below an elevated inversion. At the mine site, there was an inversion at the altitude of the plume.

The surface wind data for Test 3 are given in Volume II, Field Data. It can be seen that surface winds were generally light (< 3 m/s) during the test and that the flow was down-valley.

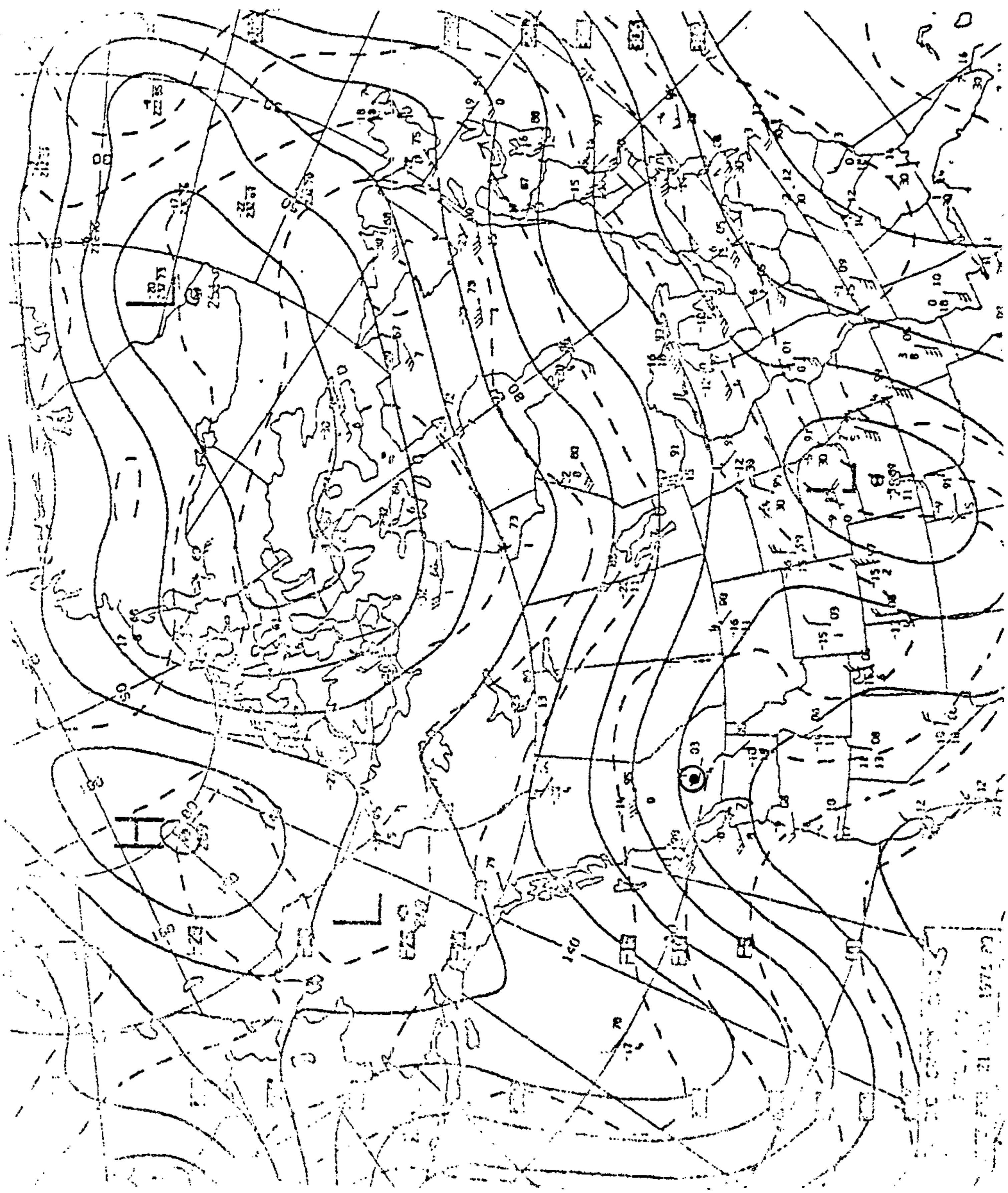


Figure 4.3-1 Surface and 700 mb maps for Test 3 1200 Z (0400 PST), February 31, 1976.

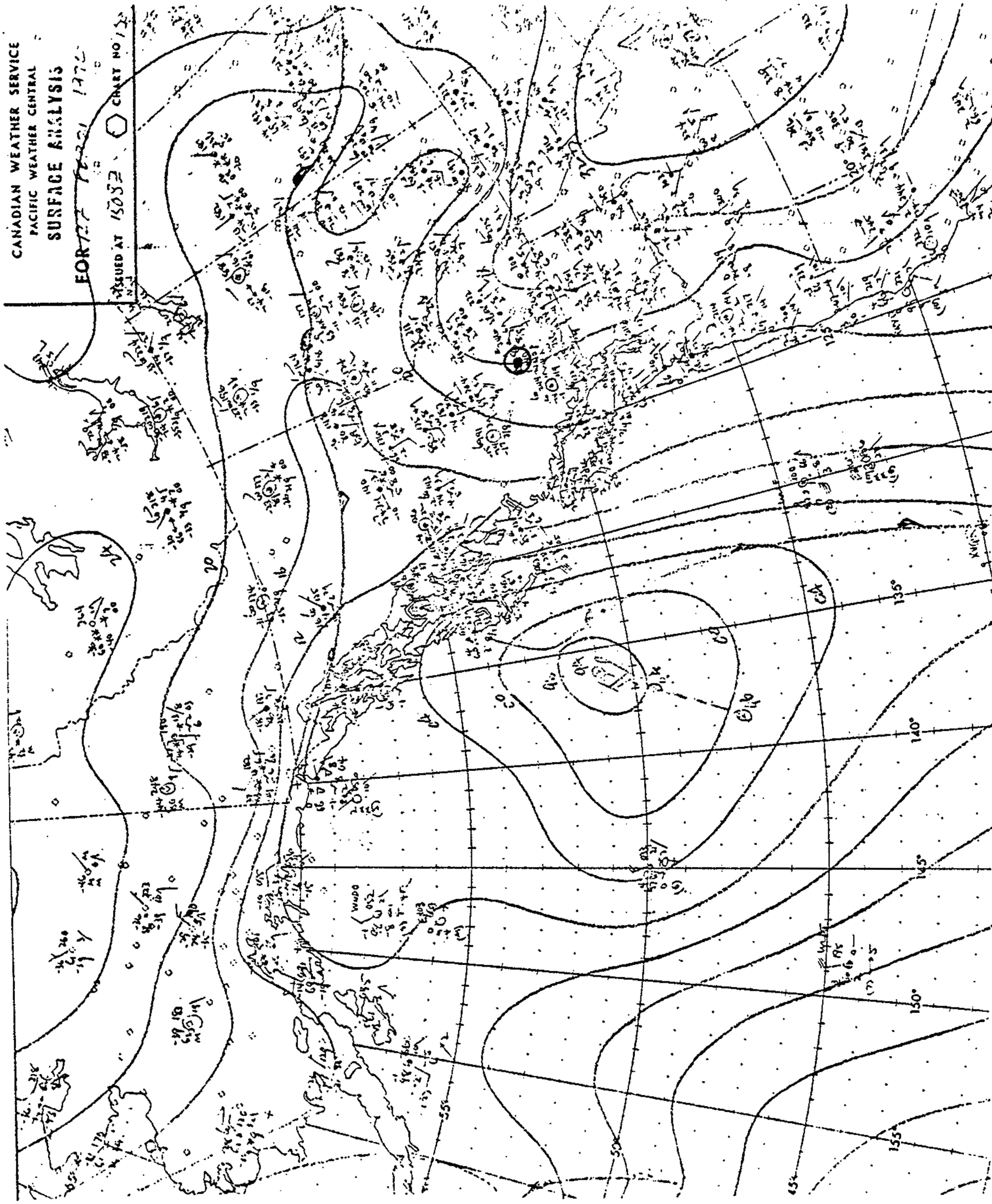


Figure 4.3-1 (Cont'd).

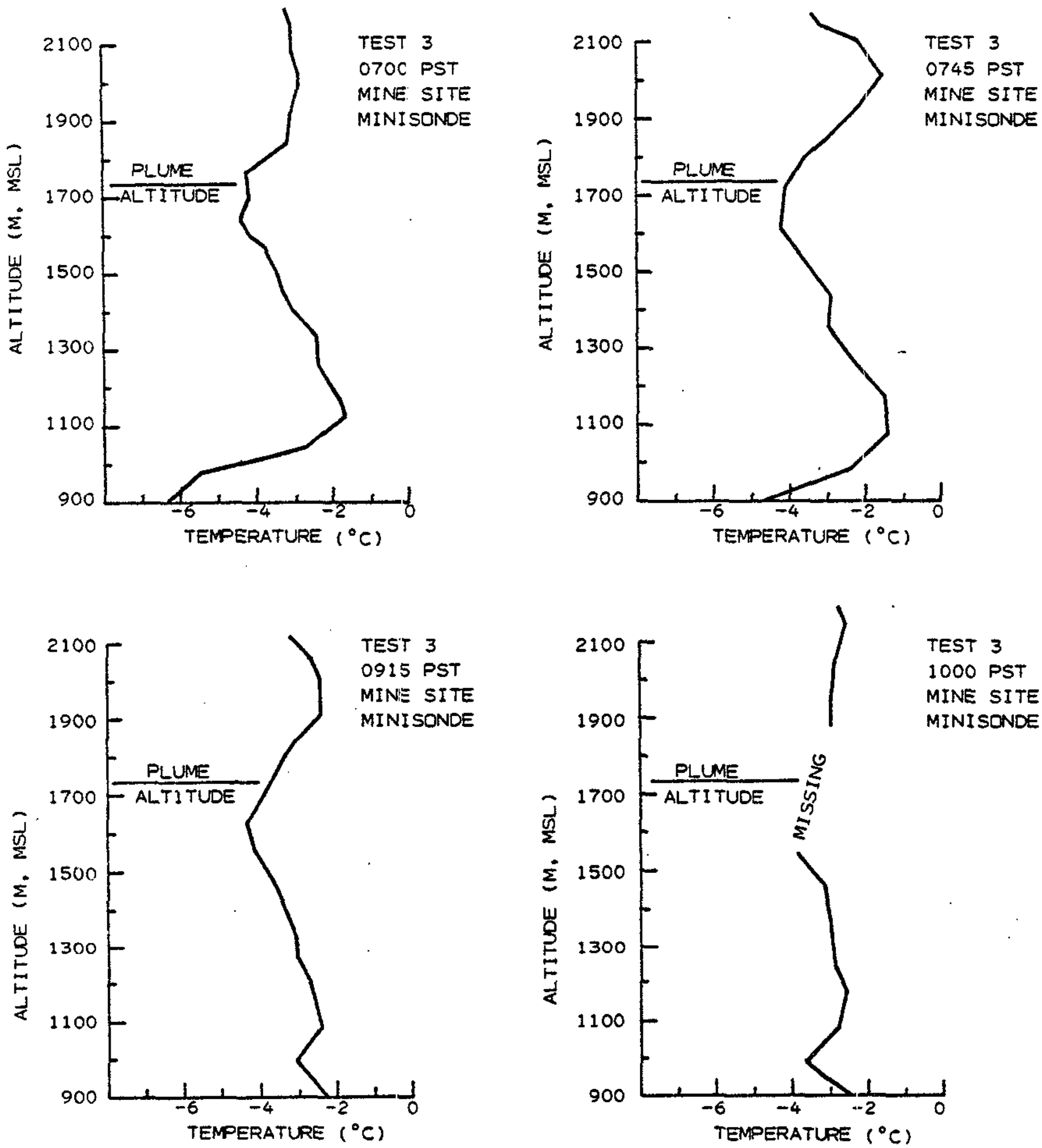


Figure 4.3-2 Vertical temperature profiles measured during Test 3 at the Mine Site using minisondes. The Mine Site is 4 km west-southwest of the source location for the test.

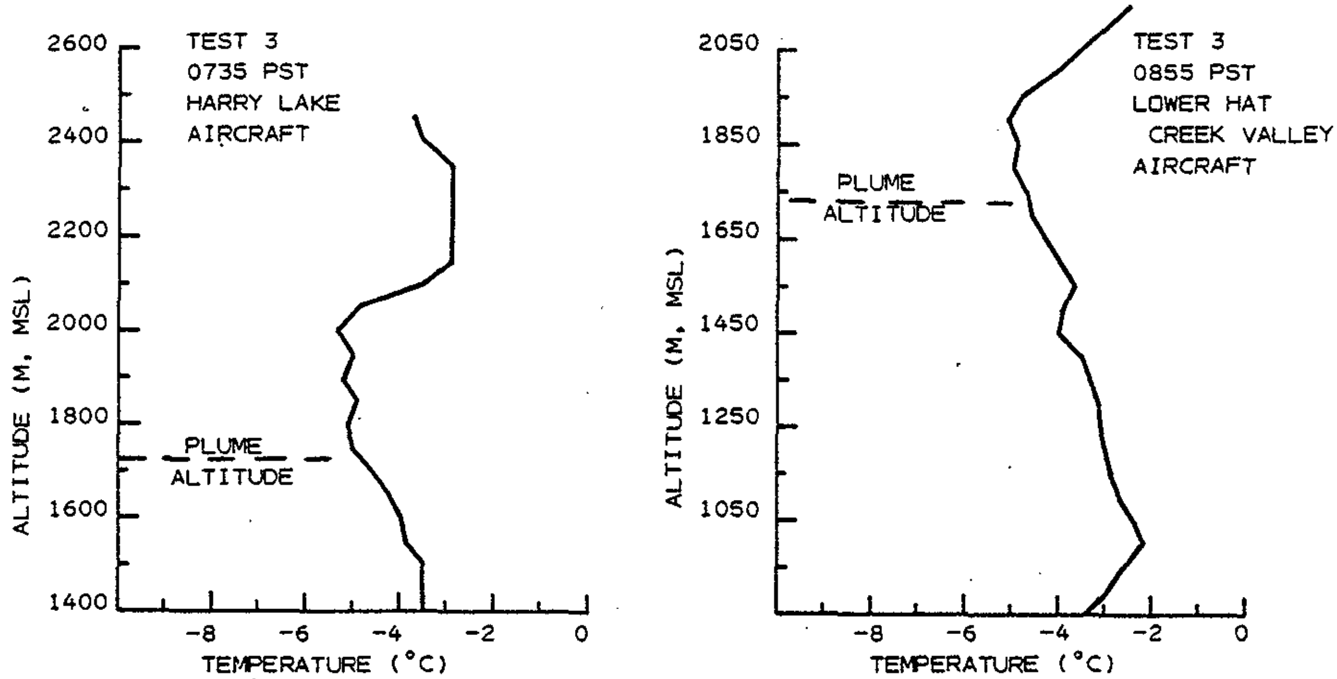


Figure 4.3-3 Vertical temperature profiles measured during Test 3 using the NAWC airborne data acquisition system. The tracer source was over Harry Lake. The other sounding was made about 4 km northwest of the source location.

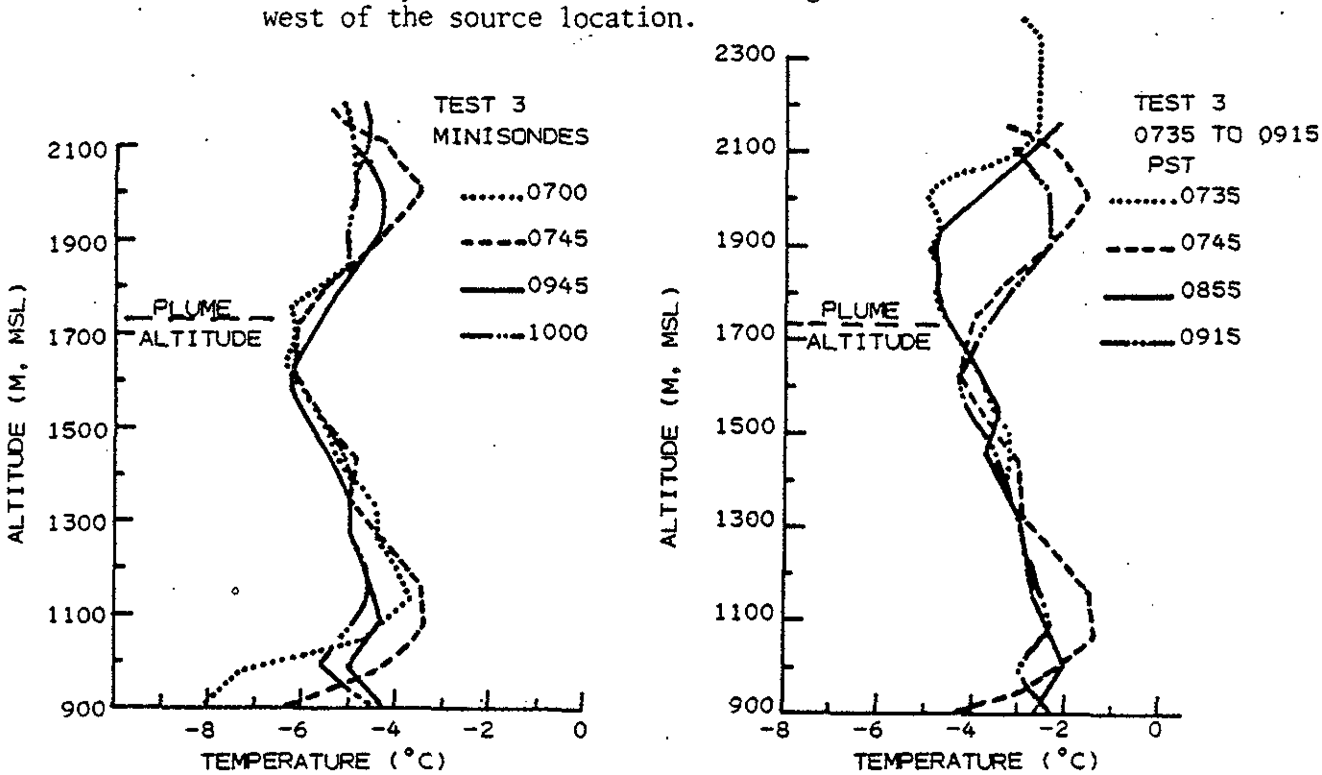


Figure 4.3-4 Superimposed Test 3 soundings. Minisondes (left) and ones between 0735 and 0915 PST (right).

The transition to up-valley flow occurred between 1200 and 1300, despite the fairly strong southerly winds aloft.

Time sections of upper wind data for Test 3 appear in Figures 4.3-5, direction, and 4.3-6, speed. It can be seen that winds at plume altitude were from the south at between 5 and 8 m/s during the test. Below this altitude winds were much lighter and more variable. The complex pattern seen in Figures 4.3-5 and 4.3-6 is evidently the product of gradient winds modified by down-valley flow at the surface and an up-valley return flow between 1000 and 1400 m MSL.

4.3.3 Tracer Dissemination. The tracer dissemination parameters for Test 3 are given in Table 4.3-1 below:

Table 4.3-1 Duration and source strength of tracer release number 3.

Location: Upper Site
Altitude: 1735 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	07:53:15	08:53:15	17,025	4.73
Oil Fog (1)	07:53:15	08:30:00	109,800	50.2
Oil Fog (2)	08:40:47	08:53:15	N/A	N/A

4.3.4 Visual and Photographic Observation of the Oil-Fog Plume for Test 3. The oil-fog plume seemed to indicate neutral to slightly stable dispersion conditions during Test 3, although lighting conditions during the test made visual observation difficult. The combination of the overcast sky conditions and snow cover made for poor contrast between the oil-fog and the background. In most instances only the most dense parts of the plume

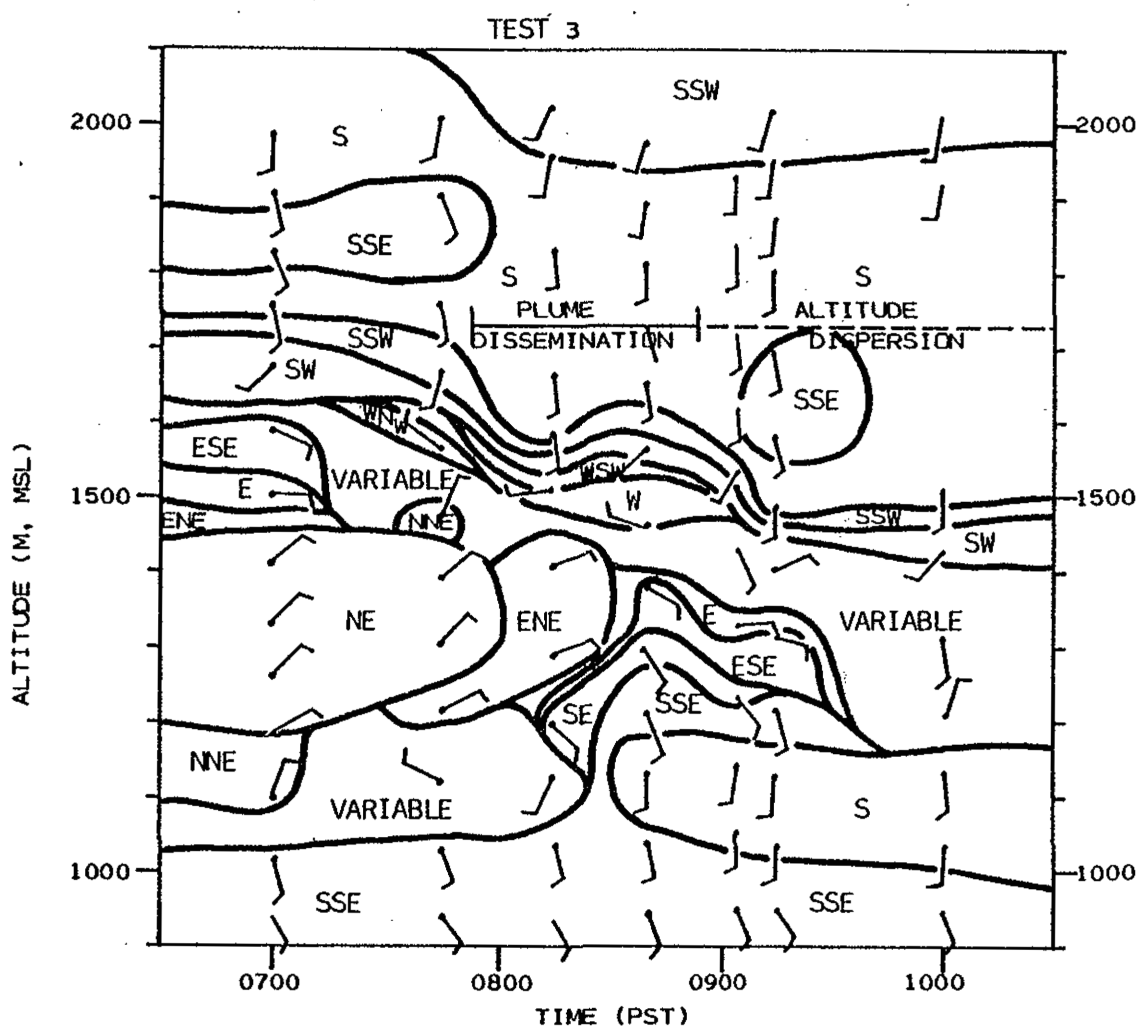


Figure 4.3-5 A time versus altitude display of wind directions aloft measured at the Mine Site during Test 3. Barbs indicate wind direction only.

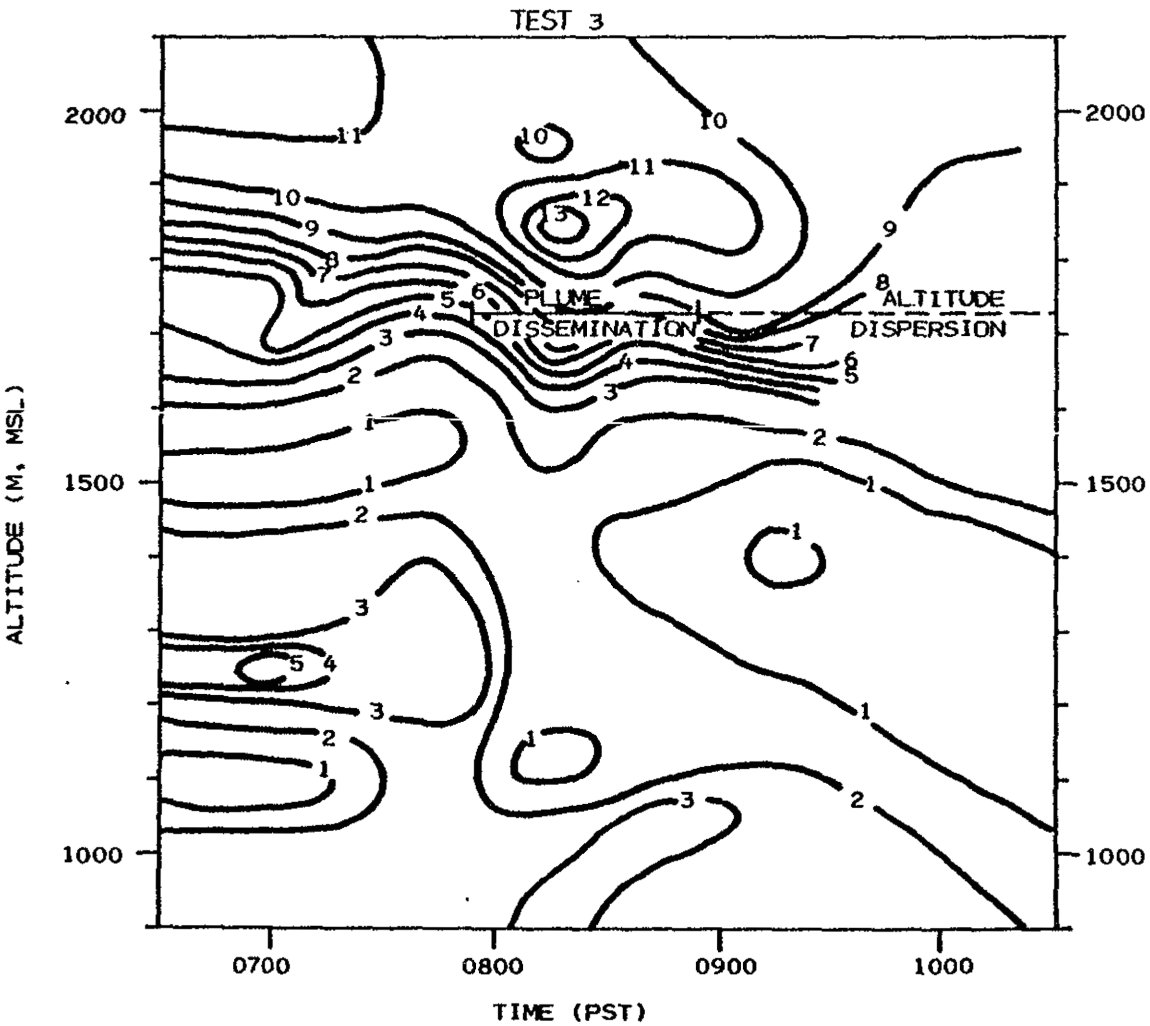


Figure 4.3-6 A time versus altitude display of wind speeds aloft measured at the Mine Site during Test 3. Wind speeds are given in m/s.

were visible. A map of the general plume trajectory is presented in Figure 4.3-7.

The plume was transported north from the source in a quite narrow and thin layer. Figure 4.3-8 shows the general appearance of the plume during the test. Figure 4.3-9 shows the lack of horizontal spreading of the plume and its direction of transport. The plume continued north and was last visible at about 15 km north of the source near Maiden Creek (see Figure 4.3-10). There was no visible evidence of any channeling of the plume by the Lower Hat Creek Valley.

4.3.5 Aerial Oil-Fog Measurements. Aerial oil-fog measurements consisted of one set of crosswind passes flown between 0802 and 0832 PST at a point 2 km downwind of the tracer source. The location is shown in Figure 4.3-11.

During this pattern twelve passes were made at altitudes between 1555 and 1890 m MSL. The maximum concentration of 7319 μgm^{-3} SO_2 was found at an altitude of 1615 m MSL. Figure 4.3-12 presents a plot of altitude vs. maximum concentration for these passes as well as the distance vs. concentration plot for the 1615 m pass. The distribution of the plume with altitude, when compared with the 0855 PST temperature sounding (see Figure 4.3-3), indicates that the plume was confined between one inversion based at about 1900 m and a weaker one below extending to about 1550 m MSL. The fact that the centerline was found to be 120 m below release altitude suggests a degree of downwash in the lee of the Trachyte Hills. The distribution also argues for some stratification of the flow, though the plume was well-mixed through the layer between the two inversions.

Measurements of σ_y and σ_z have been made and appear in Figure 4.3-13. Dispersion coefficients appropriate for C-D stability are

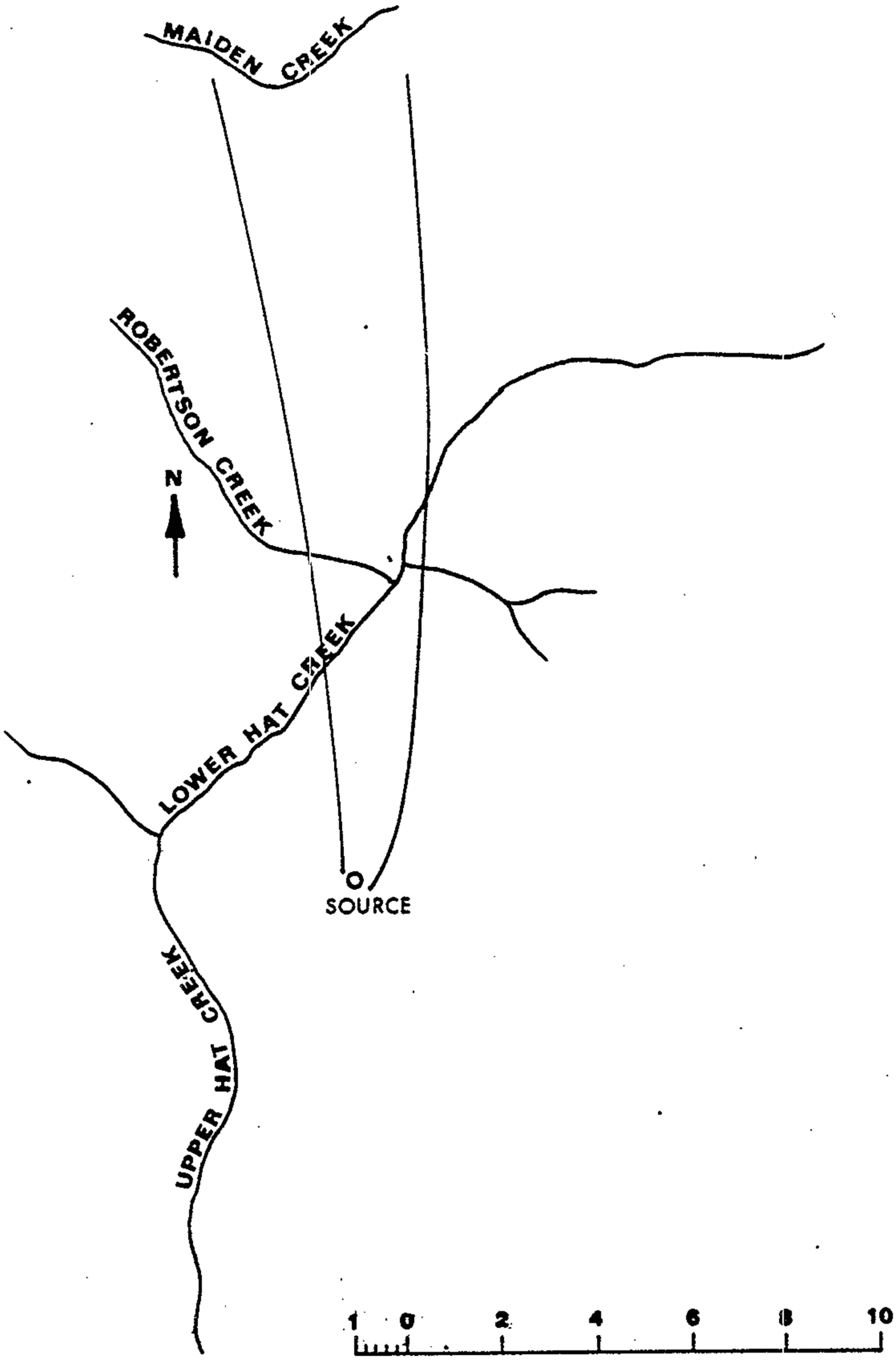


Figure 4.3-7 Approximate visible plume boundary during Test 3.

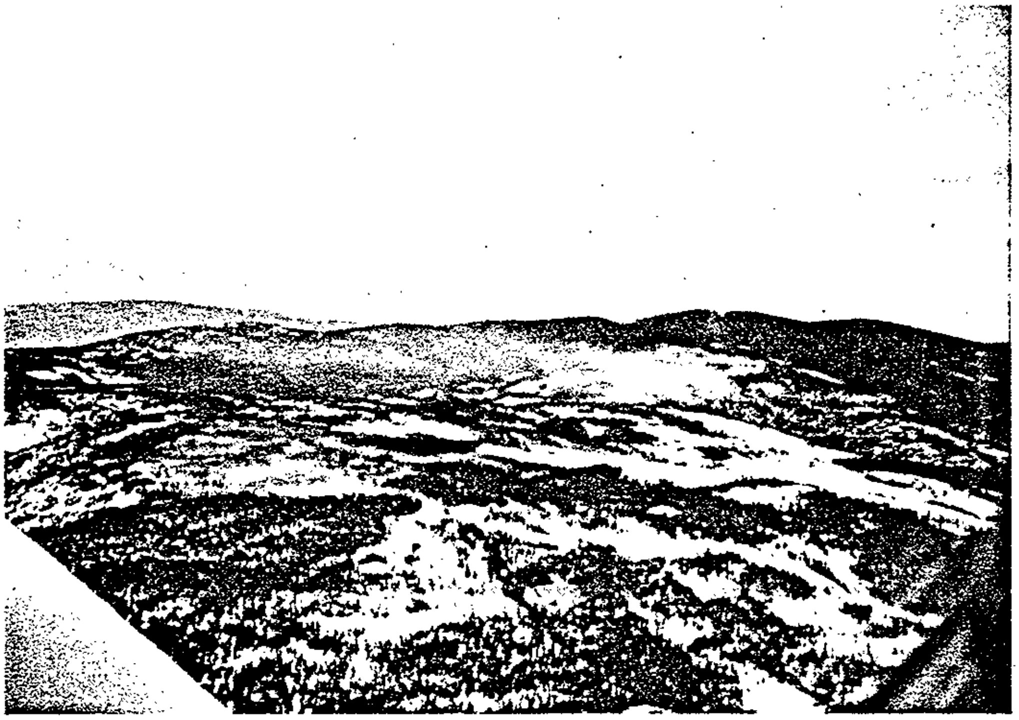


Fig. 4.3-8 A photograph of the Test 3 oil-fog plume taken at 0847 PST. The view is toward the south-southeast.

Fig. 4.3-9 A photograph of the Test 3 oil-fog plume taken at 0819 PST. The view is from upwind of the source.

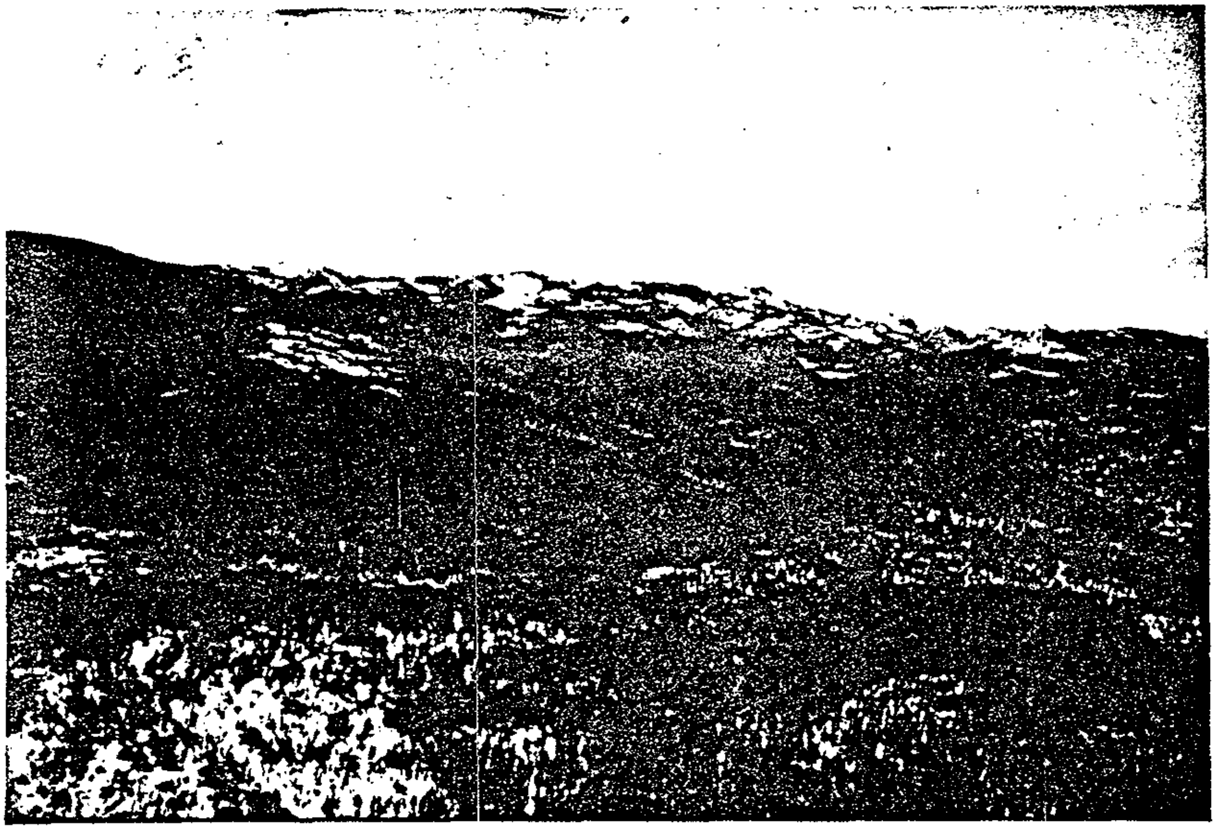


Fig. 4.3-10 A photograph of part of the Test 3 oil-fog plume taken at 0918 PST. The view is toward the north-northwest and is of an area about 15 km north of the Harry Lake site.

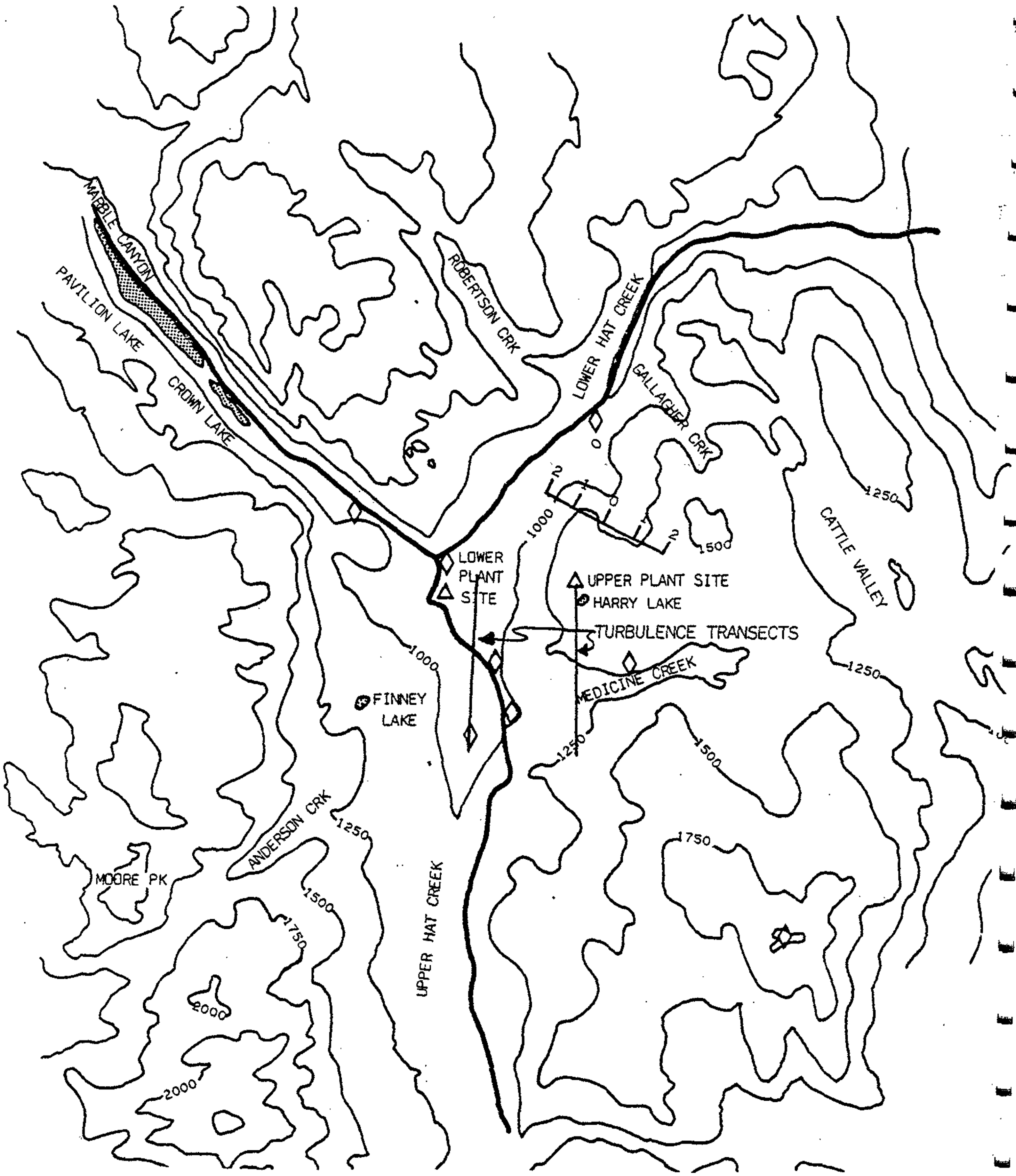


Figure 4.3-11 Location of oil-fog crosswind patterns and turbulence transects, Test 3. Distances are in kilometers.

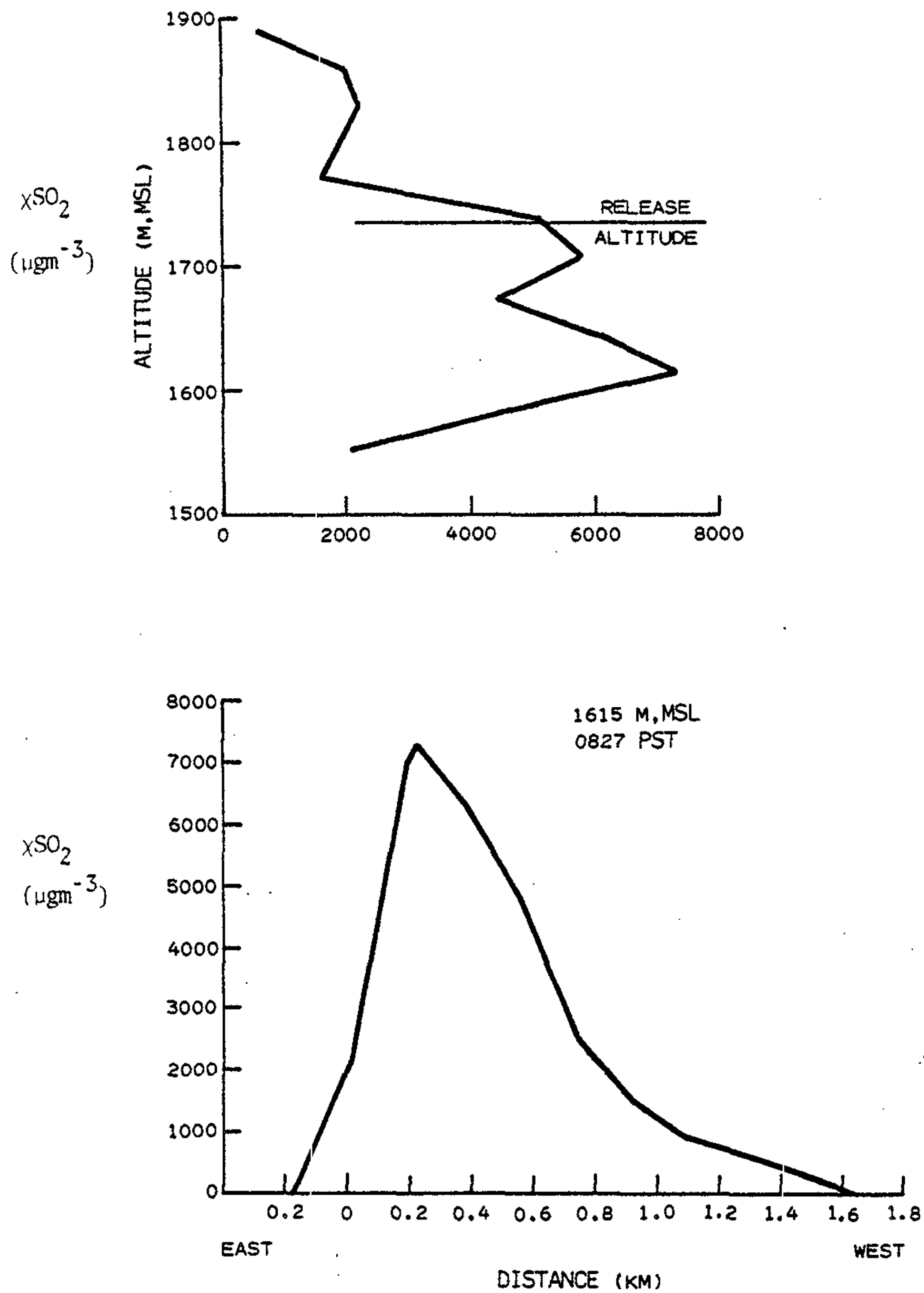


Figure 4.3-12 Horizontal and vertical plume centerline distributions, Test 3.

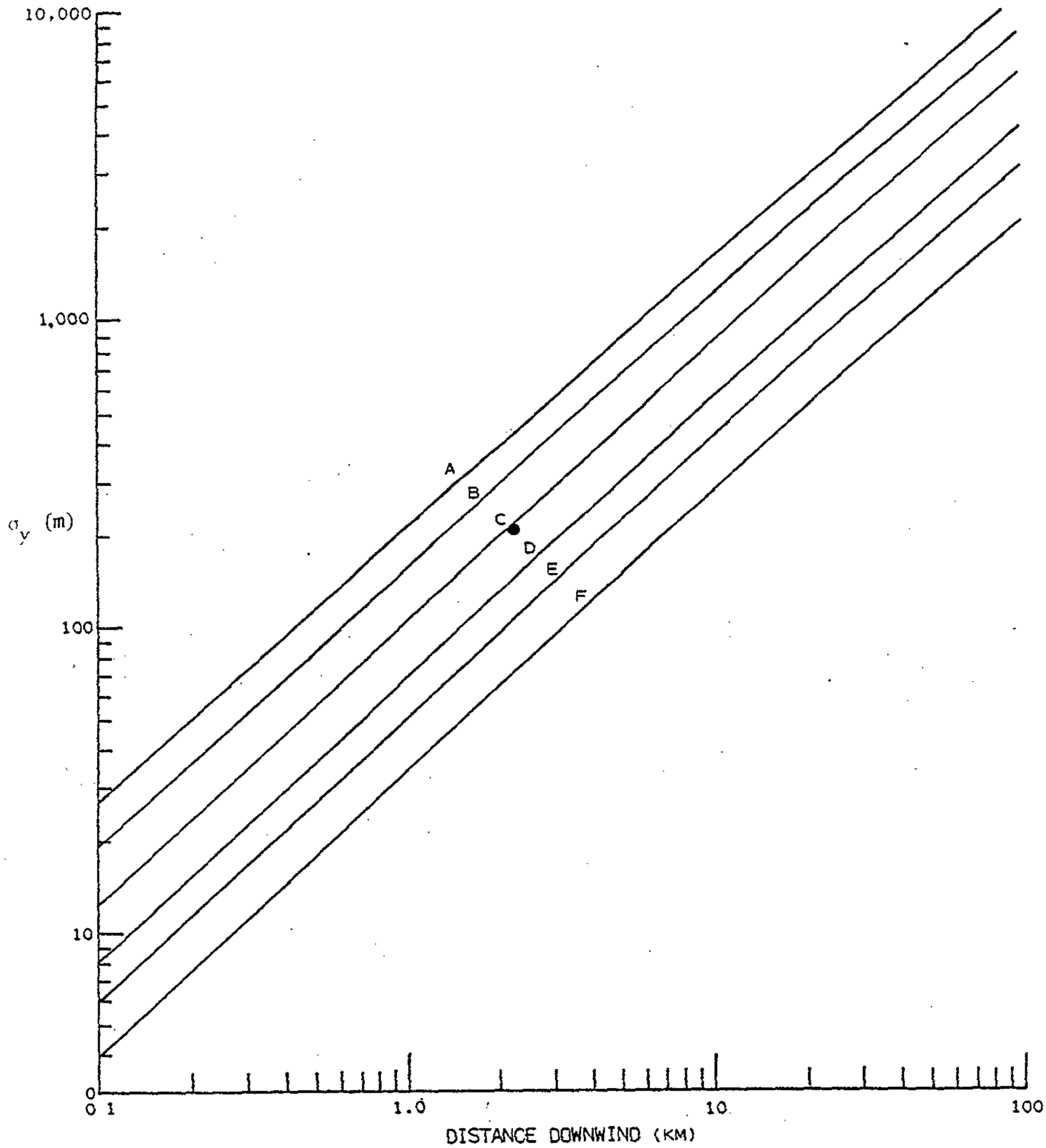


Figure 4.3-13 Measured values of σ_z and σ_y for Test 3.

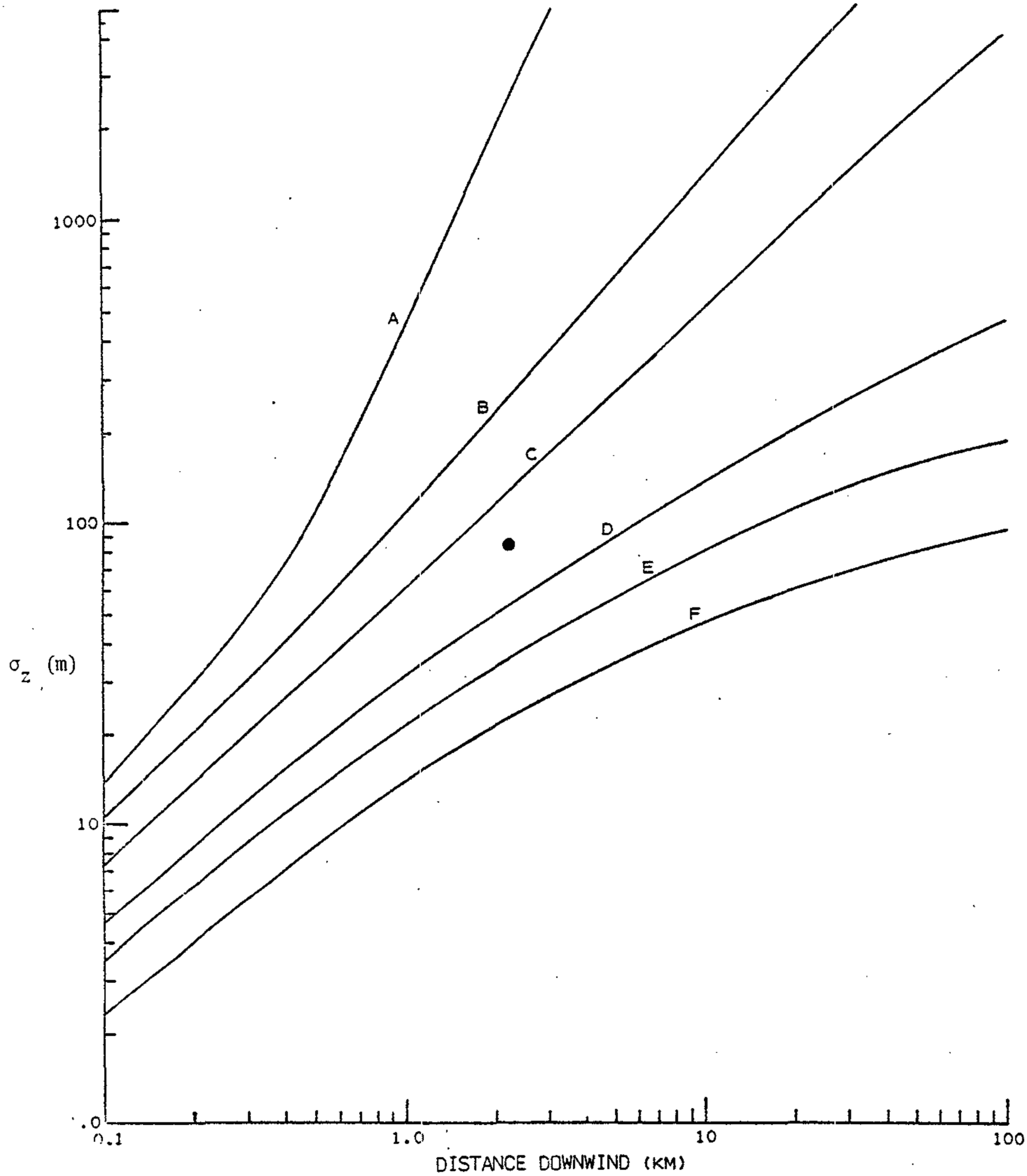


Figure 4.3-13 (Cont'd).

indicated. Similarly, the value of $\frac{\chi \bar{u}}{Q}$, Figure 4.3-14, suggests a dilution rate associated with neutral conditions. Over flat terrain, with the observed 7 m/s wind speed and fairly stable temperature structure, D-E dispersion would be expected.

The plume centerline showed a slight tilt towards the southeast with decreasing altitude. This type of behavior was noticed during the Test 2 as well, and is evidently caused by more extensive terrain channeling at lower altitudes.

4.3.6 Aerial SF_6 Measurements. A total of 19 aerial SF_6 samples were gathered during Test 3. Figure 4.3-15 shows the location of these samples. Table 4.3-2 contains supplementary information pertaining to time, altitude, and measured concentration. The maximum measured concentration was equivalent to 194 μgm^{-3} SO_2. This value was measured at 1525 m MSL, 2.9 km downwind from the release.

Sampling began with three samples taken near the releases (3H1, 3H2, 3H3) at altitudes of 1525, 1400, and 1495 m MSL. Sample 3, taken 2.9 km from the release, contained the maximum measured SF_6 concentration for the test, equivalent to 194 μgm^{-3}. Next, a cross-valley pattern was flown at 1495 m MSL and again at 1370 m MSL, about 3.8 km from the release (samples 3H4-3H11). Two samples had measurable concentrations on the first pass versus one on the second (lower) pass. A second cross-valley pattern was found 5.2 km from the release at Gallagher Creek. These passes were flown at altitudes of 1370 and 1280 m MSL (samples 3H12-3H19). Two samples showed measurable concentrations over upper Gallagher Creek, one over the center of the valley.

The generally low concentrations found during aerial sampling for Test 3 suggest that there was less terrain channeling than observed during Test 2 and that there was little downward transport of the tracer material below about 1500 m MSL.

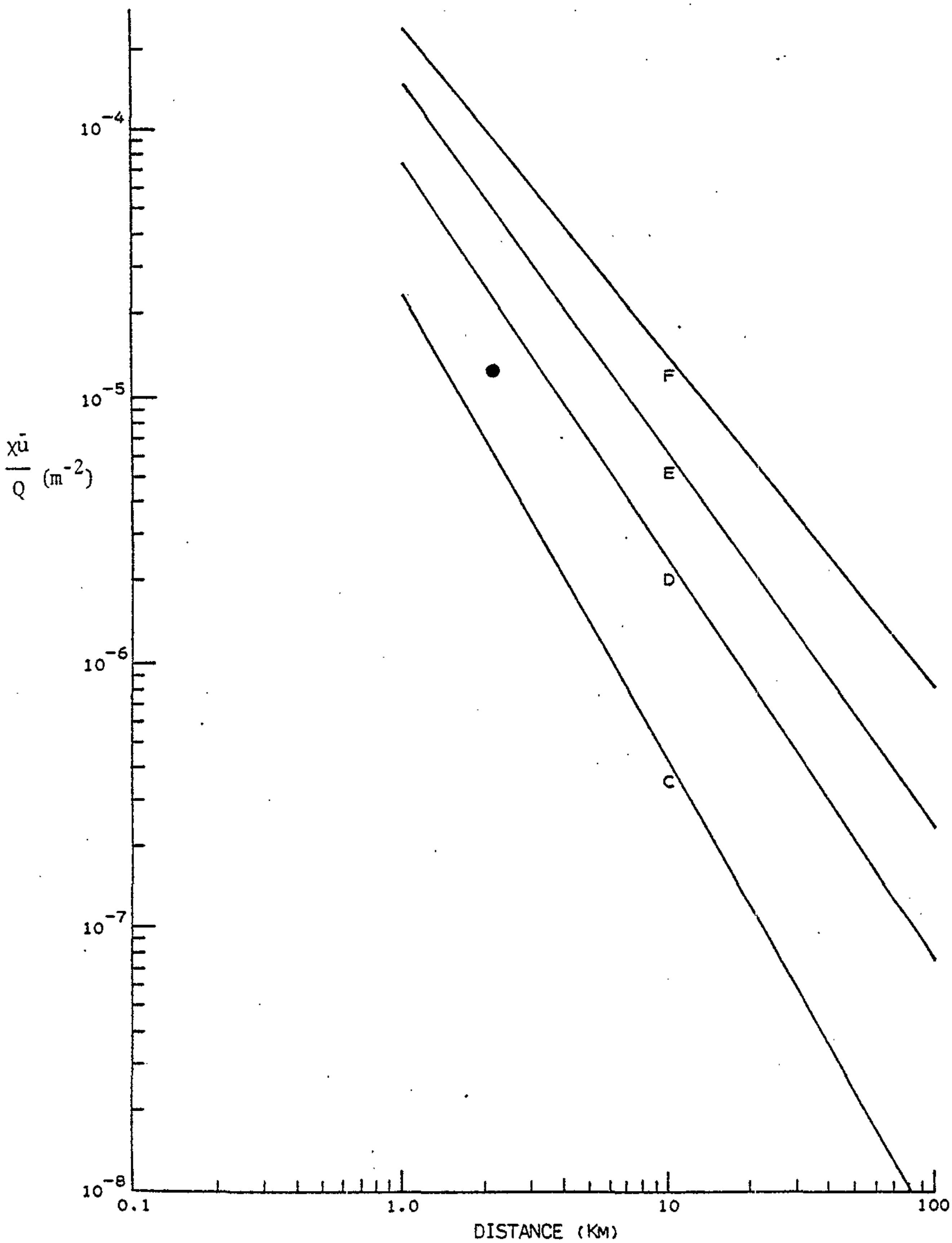


Figure 4.3-14 Measured values of $\frac{\chi\bar{u}}{Q}$ for Test 3.

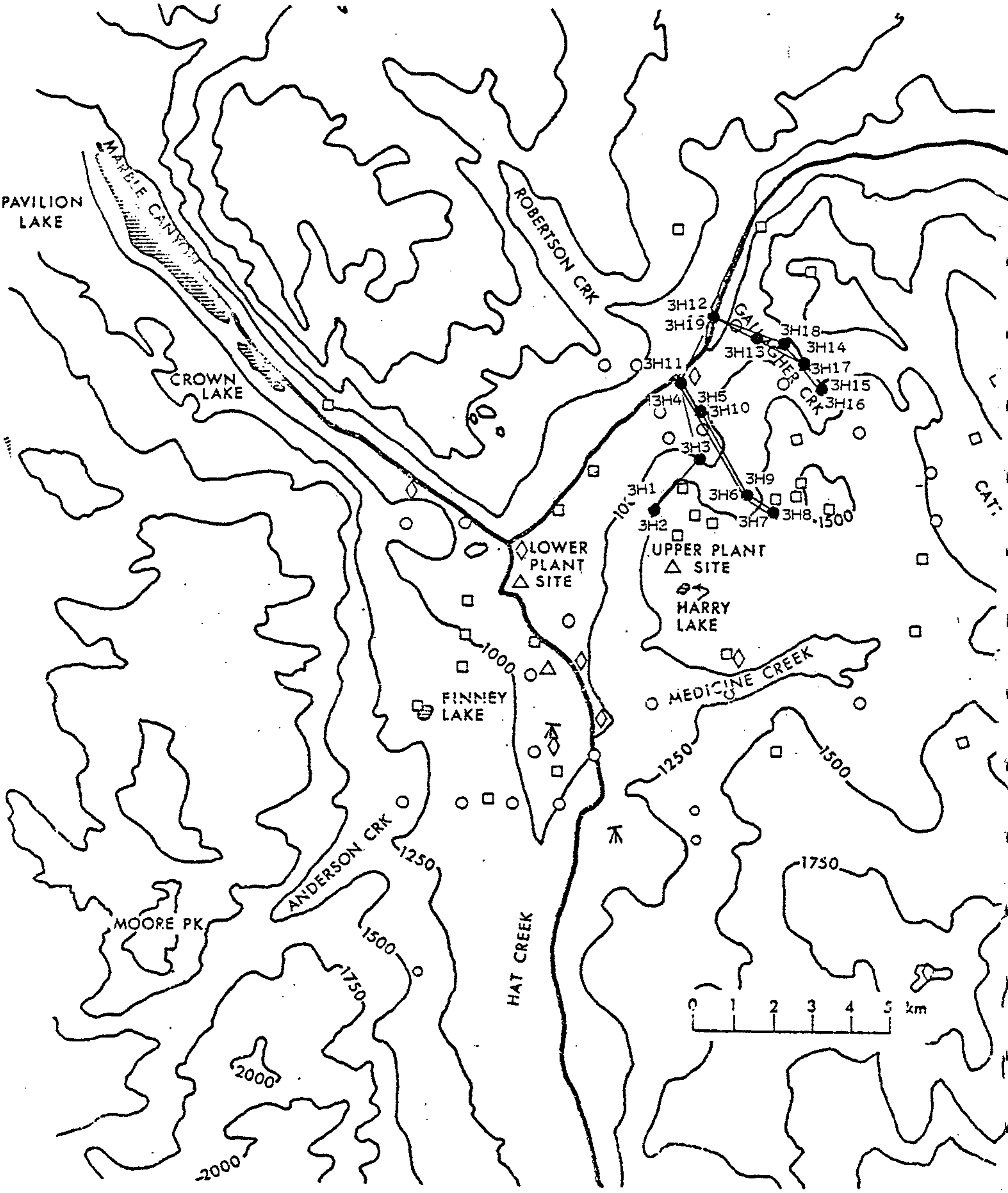


Figure 4.3-15 Location of aerial SF_6 samples, Test 3.

Table 4.3-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	Altitude (m) AGL	Time (PST)	Sample Time (min)	χSO_2 ($\mu g m^{-3}$) Ambient	χSO_2 ($\mu g m^{-3}$) NTP
3H1	1.6	1525	275	0805	1	48	54
3H2	1.6	1400	150	0809	1	48	54
3H3	2.9	1495	495	0813	1	194	218
3H4	3.3	1495	720	0820	1	97	109
3H5	2.8	1495	595	0823	1	0	0
3H6	2.3	1495	345	0825	1	0	0
3H7	3.0	1495	220	0829	1	48	54
3H8	3.0	1370	95	0831	1	0	0
3H9	2.3	1370	270	0833	1	0	0
3H10	2.8	1370	520	0836	1	0	0
3H11	3.3	1370	645	0839	1	97	109
3H12	6.5	1370	620	0845	1	0	0
3H13	6.4	1370	520	0847	1	0	0
3H14	6.1	1370	370	0850	1	0	0
3H15	6.0	1370	120	0855	1	97	109
3H16	6.0	1280	30	0857	1	0	0
3H17	6.1	1280	280	0900	1	97	109
3H18	6.5	1280	330	0902	1	0	0
3H19	6.5	1280	530	0906	1	48	54

4.3.7 Surface SF_6 Measurements. A total of ten sampler locations was employed during Test 3. The locations of the samplers are shown in Figure 4.3-16. Table 4.3-3 gives the altitude, time, and measured concentrations for the samples. The maximum concentration measured by the surface network was equivalent to 97 μgm^{-3} SO_2 over three-hour averaging time. All sites showed measurable concentrations at some time during the test, though all were rather low. These data indicate that plume dispersion towards the ground was limited during this test, a conclusion supported by the aerial SF_6 sampling data.

4.3.8 Turbulence Measurements. The turbulence measurements made during the oil-fog crosswind passes are shown in Figure 4.3-17. It can be seen that both the values $\bar{\varepsilon}$ and I appear to be correlated with altitude, with $\bar{\varepsilon}$ increasing and I decreasing with height. The distribution of $\bar{\varepsilon}$ appears to reflect the decreasing shear velocities with decreasing height through this layer (see Figure 4.3-6). Concurrently, the distribution of intermittence suggests an environment of continuous turbulence at higher altitudes and one of occasional disturbances at lower altitudes. The turbulence dissipation rates indicate conditions of very rapid dispersion above and more stable conditions below about 1600 m MSL.

Three special turbulence transects were made over Hat Creek Valley and over the ridges to the east to compare the turbulence regimes over each. The results of these transects are plotted on Figure 4.3-17 (marked "valley" and "ridge"). It can be seen that turbulence values were less and intermittence higher over the valley. A second transect was made over the valley at 1525 m MSL. As was the case with the other data, turbulence values were lower and intermittence values were higher at this lower altitude. These measurements would suggest dispersion rates typical of C stability over the ridges and neutral atmosphere rates over the valley at 1740 m MSL. Somewhat stable conditions are indicated over the valley at 1525 m MSL.

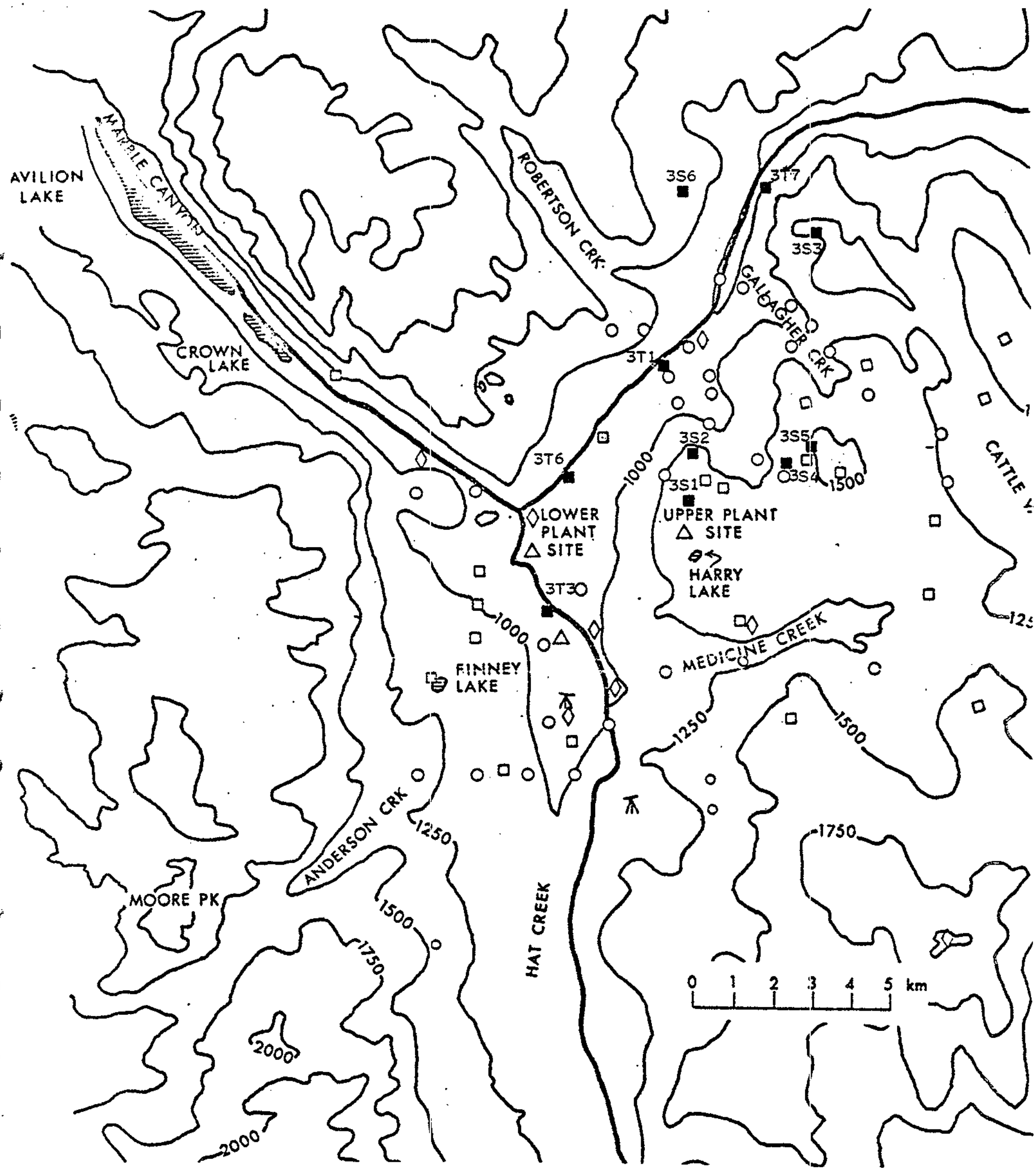


Figure 4.3-16 Location of surface SF_6 samplers, Test 3.

Table 4.3-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On (PST)	Time Off (PST)	Sampling Time (Min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
3S1	0.75	1370	0809	0839	Malf.	-	-
			0839	0909	30	97	109
			0909	0939	30	0	0
			0939	1009	30	48	54
			1009	1016	7	0	0
3S2	2.0	1280	0814	0844	30	0	0
			0844	0914	30	48	54
			0914	0944	30	48	54
			0944	1014	30	97	109
			1014	1021	7	48	54
3S3	8.4	1275	0821	0851	Malf.	-	-
			0851	0921	30	48	54
			0921	0951	30	0	0
			0951	1021	30	48	54
3S4	3.3	1310	0829	0859	30	0	0
			0859	0929	30	48	54
			0929	0959	30	48	54
			0959	1029	30	97	109
3S5	3.9	1340	0845	0915	30	97	109
			0915	0945	30	48	54
			0945	1015	30	97	109
3S6	8.8	1115	0853	0923	30	0	0
			0923	0953	30	48	54
			0953	1023	30	48	54
			1023	1046	23	97	109
3T1	4.3	925	0825	0925	60	0	0
			0925	1025	60	48	54
			0740	1040	180	97	109
3T6	3.3	825	0845	0915	30	97	109
			0915	0945	30	48	54
3T7	9.0	725	0855	0955	60	97	109

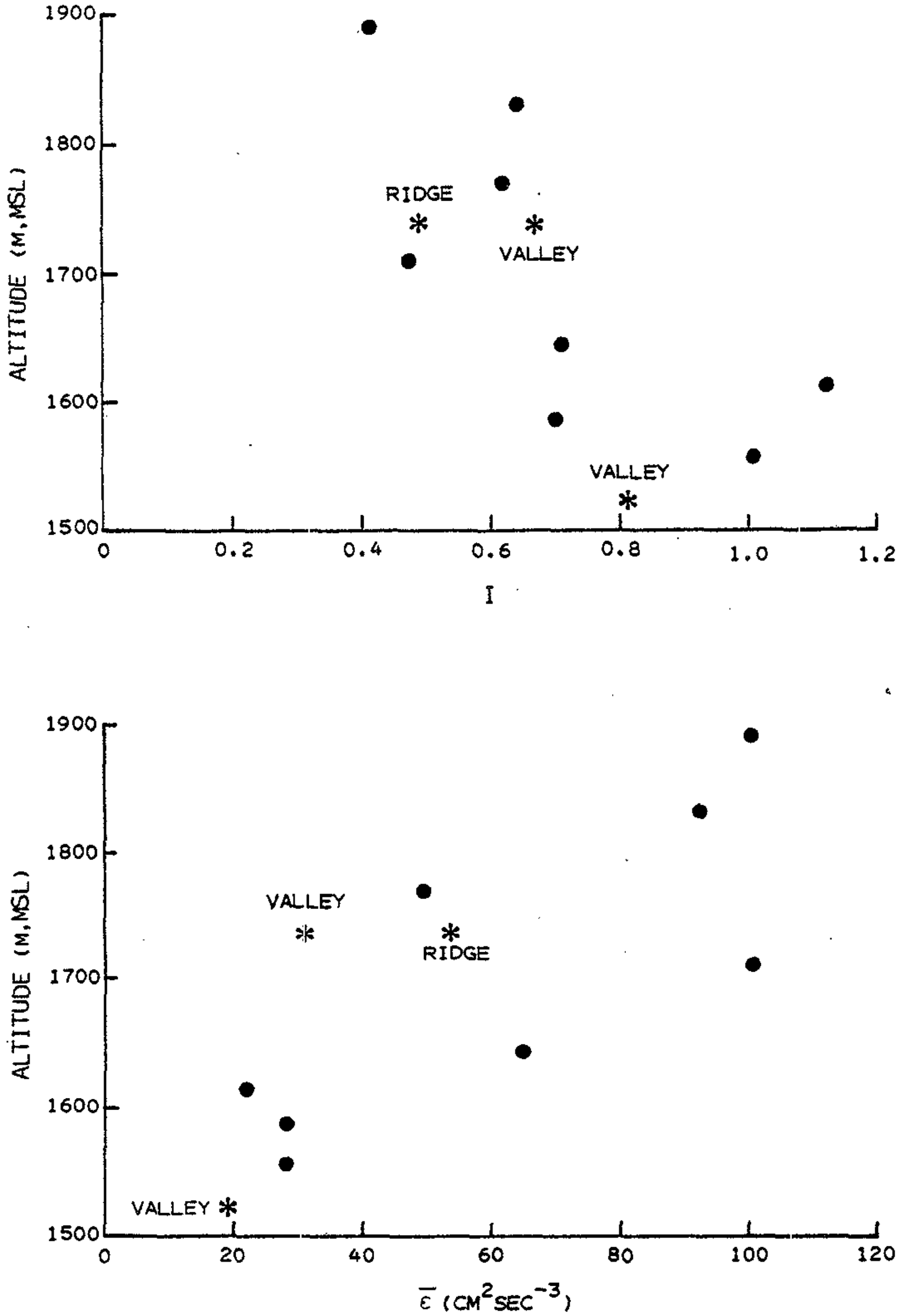


Figure 4.3-17 Turbulence measurements vs. altitude, Test 3. Asteriks indicate measurements made during transects.

4.3.9 Summary of Test 3. The third tracer release was made at the upper plant site. Though the temperature profiles show moderate stability at this level, wind speeds at plume height (8-10 m/s) indicate neutral-type dispersion conditions. Winds at plume level during the test were from the south, making conditions conducive to investigate downwash into the Lower Hat Creek Valley.

The maximum surface concentration measured during Test 3 was equivalent to 97 μgm^{-3} SO_2 for sampling times of 30, 60, and 90 minutes.

Visual observations of the oil-fog plume suggest that the plume moved almost due north throughout the test with little indication of channeling down Lower Hat Creek Valley. Extensive aerial SF_6 sampling, carried out in the lower valley to the east of the release, yielded very low concentrations and substantiates this observation. Ground level SF_6 concentrations were similarly low, suggesting little downward transport. No samplers were deployed on the south-facing slopes of Lower Hat Creek opposite the release, however, where surface impact may have been higher.

The aerial oil-fog measurements show a normalized centerline dilution rate indicative of C-D stability, though the temperature structure was somewhat stable. Turbulence dissipation rates were very high above release altitude but dropped to stable atmosphere values near 1600 m MSL. Turbulence values were shown to be characteristic of slightly unstable conditions at plume altitude over the eastern ridges and characteristic of somewhat stable conditions at the same altitude over the center of Hat Creek Valley.

This test is an example of a coning plume rapidly dispersed by shear- and terrain-induced turbulence, despite a slightly stable temperature structure. Slight downwash was observed into the

Lower Hat Creek Valley but the combination of excellent dispersion, moderate wind speeds, and stable conditions near the surface minimized surface impact.

4.4 Test Number Four, March 25, 1976

This test was conducted from the lower valley site. The meteorological conditions were conducive to examining possible impact of the plume on the Trachyte Hills under west ly flow.

4.4.1 Synoptic Setting. The surface and 700-mb maps for 0400 PST, March 25, are shown in Figure 4.4-1. The dominant influence was a weak ridge at 850 mb under zonal flow at 500 mb. Cold air aloft caused numerous snow showers throughout southern British Columbia, but not in the immediate Hat Creek Valley area. The surface analysis showed cyclonic systems both west and east of the area, but a weak surface high pressure ridge extended over Hat Creek. The initially west to northwest gradient wind backed to the southwest as the day progressed.

4.4.2 Meteorological Parameters for Test 4. A minisonde was taken at 0935 PST (see Figure 4.4-2) and indicated that the air mass was well mixed with neutral stability. The plume altitude wind directions were highly variable, from 280° at 1030 PST to 190° at 1330 PST, thus sweeping a wide arc during the release period. Wind speed varied between 6-9 m/s.

A single theodolite pibal taken at 1047 PST from the mine site showed plume altitude winds to be from 279° at 6.5 m/s. Three constant volume balloons were released between 1130 and 1340 PST. The first indicated winds to be between 230° and 250° at about 10 m/s. This balloon maintained its float level, but gradually approached the rising terrain at the Trachyte Hills and eventually snagged a tree 2 km north of Harry Lake. The second, launched at 1200 PST, showed plume altitude winds to be

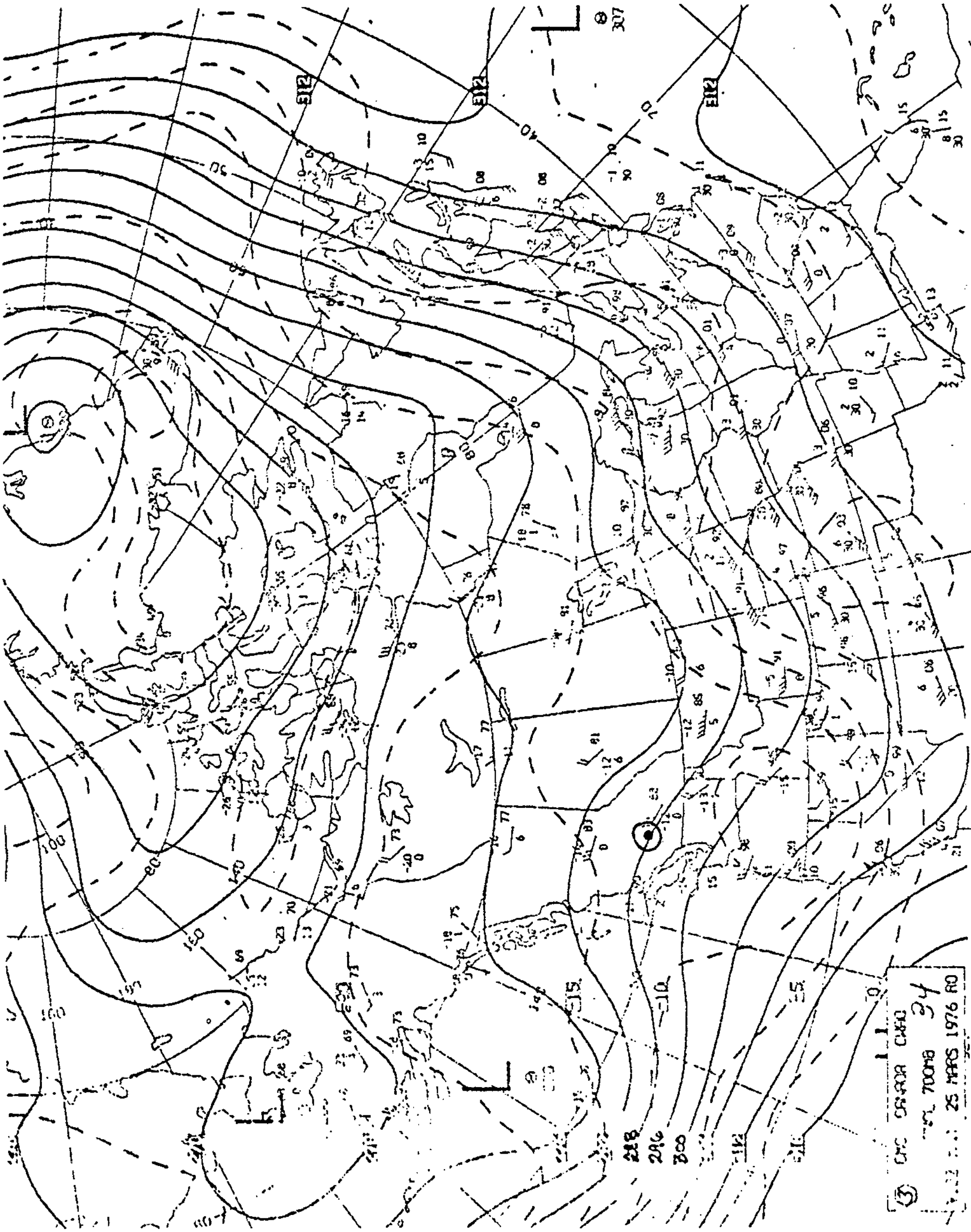


Figure 4.4-1 Surface and 700 mb maps for 0400 PST, March 25.

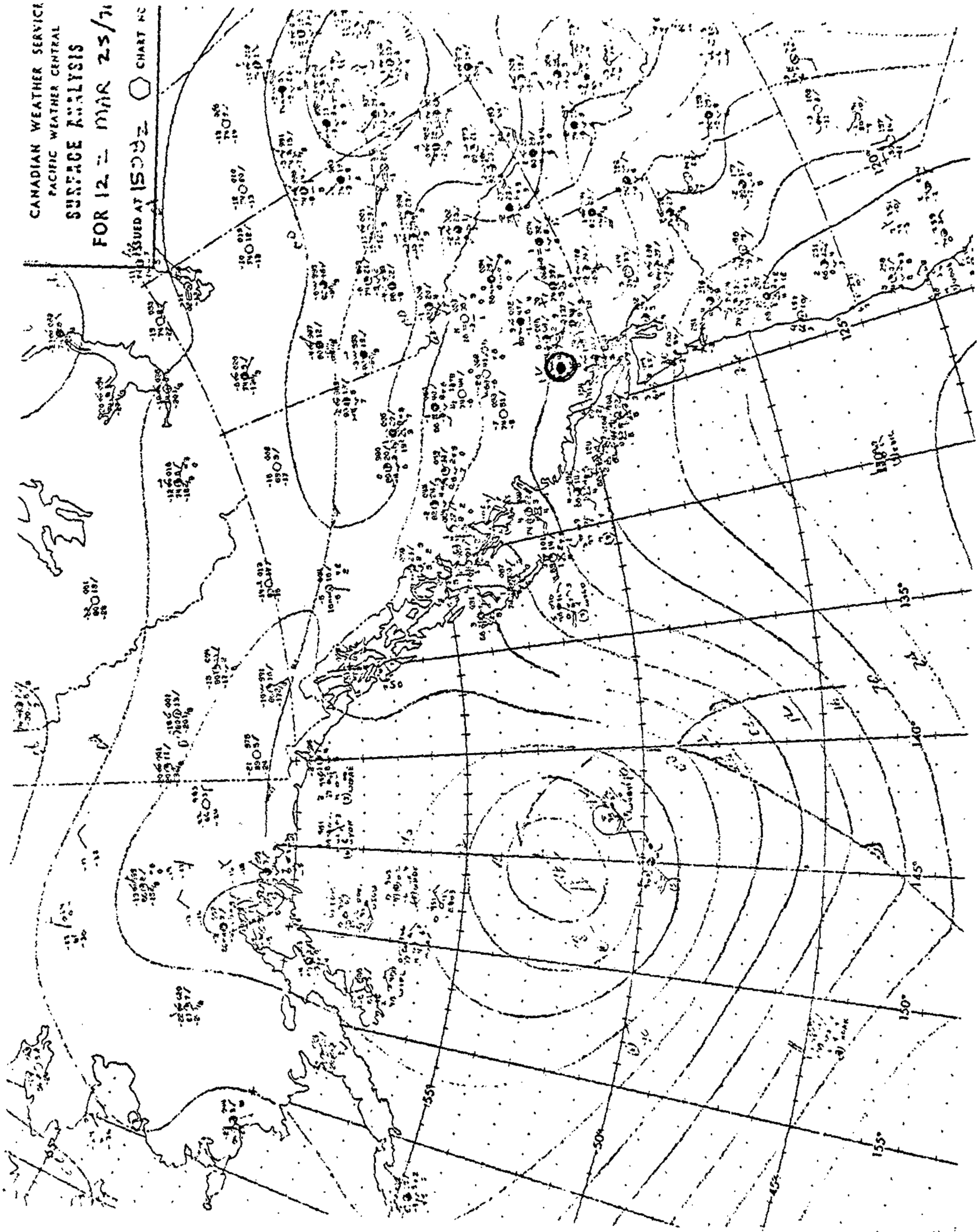


Figure 4.4-1 (Cont'd).

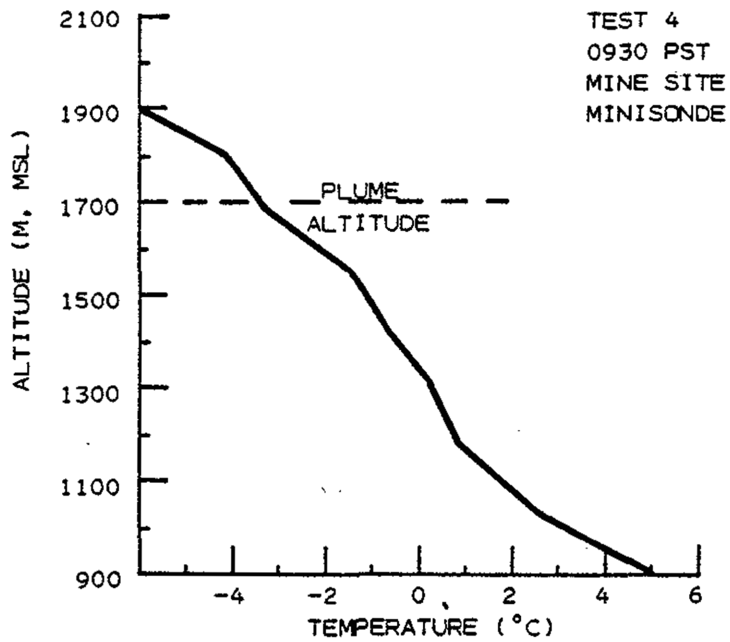


Figure 4.4-2 Vertical temperature profile measured during Test 4 at the mine site using minisondes.

between 215° and 220° at about 8 m/s. The third balloon, launched at 1337 PST, indicated the flow at plume altitude to be between 210 and 215° at about 9 m/s. This balloon maintained its float level and eventually struck a treetop near the mouth of Gallagher Creek. The tracks of the second and third balloons are shown in Figures 4.4-3 and 4.4-4.

The surface wind observations for Test 4 are presented in Volume II, Field Data. It can be seen that moderate west to southwest winds were present in the valley at the time of release. A slight diurnal change can be noted in the wind directions, but the normal valley circulation was not as prevalent as seen in previous tests due to the stronger winds aloft and the neutral atmospheric conditions near the surface.

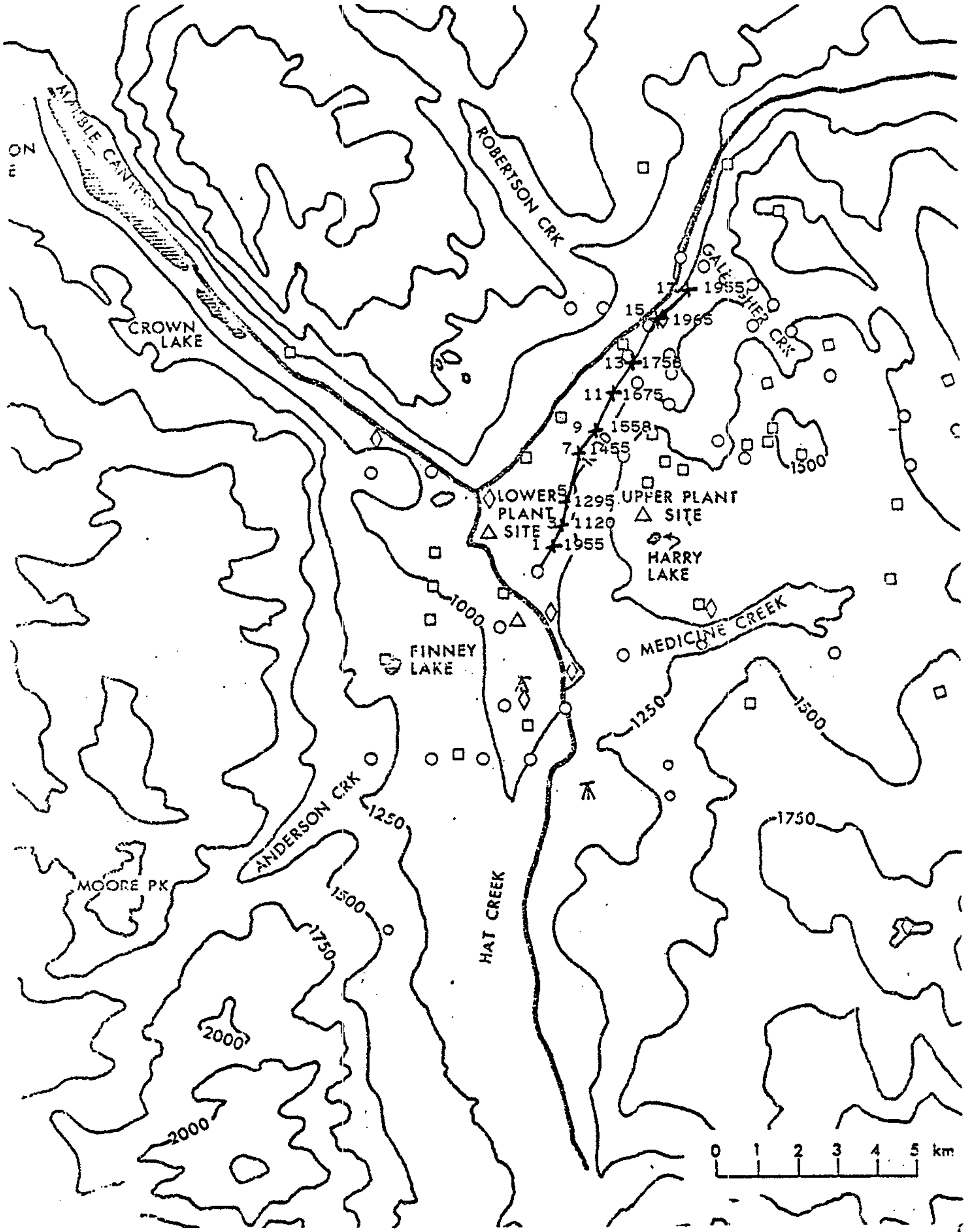


Figure 4.4-3 Track of C-V balloon launched 1200 PST, March 25, 1976. Altitudes are given in m, MSL; elapsed time in minutes.

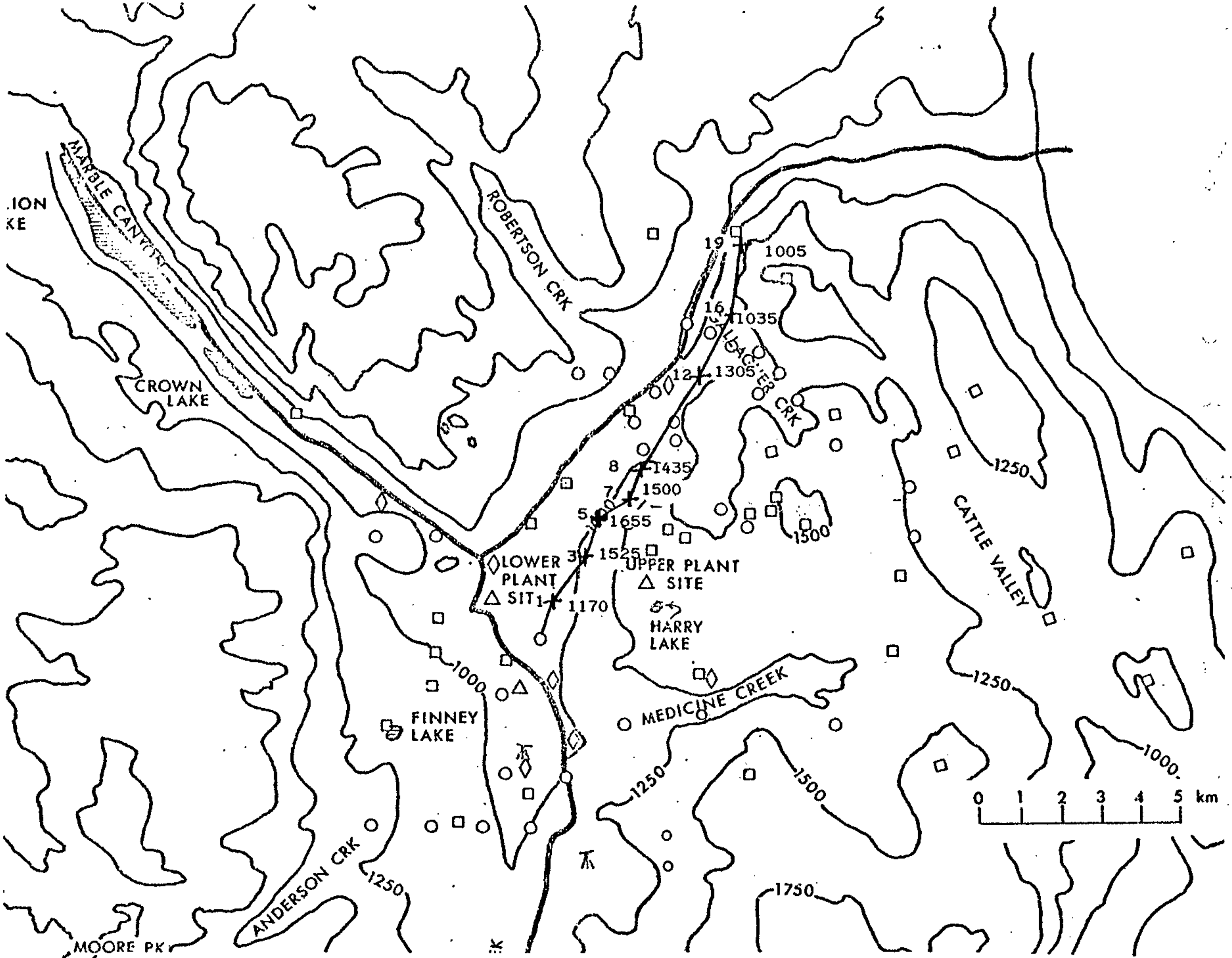


Figure 4.4-4 Track of C-V balloon launched 1337 PST, March 25, 1976. Altitudes are given in m, MSL; elapsed time in minutes.

4.4.3 Tracer Release Parameters. The tracer release parameters for Test 4 appear in Table 4.4-1 below.

Table 4.4-1 Duration and source strength of tracer release number 4.

Location: Lower Site
Altitute: 1500 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	11:05:00	11:49:00	14,870	5.63

This release was carried out by a helicopter circling at 20 m/s. Strong winds over the site occasionally displaced its circle as much as 500 m to the east and north of the site.

4.4.4 Ground Level SF_6 Measurements. A network of single and sequential samplers was laid in an arc, as shown in Figure 4.4-5. The measured concentrations and sampling parameters for each sampler are presented in Table 4.4-2.

The concentrations were in excess of 11,880 μgm^{-3} SO_2 at six of the eight sites with a maximum measured concentration of 36,354 μgm^{-3} SO_2 at site NR6. In general, the concentrations appear to be related to sample altitude. The highest samplers received the highest concentrations and the lowest samplers received the lowest.

4.4.5 Summary Discussion of Test Number 4. The high concentrations of SF_6 in Test 4 are difficult to explain considering the atmospheric conditions which prevailed. The minisonde data

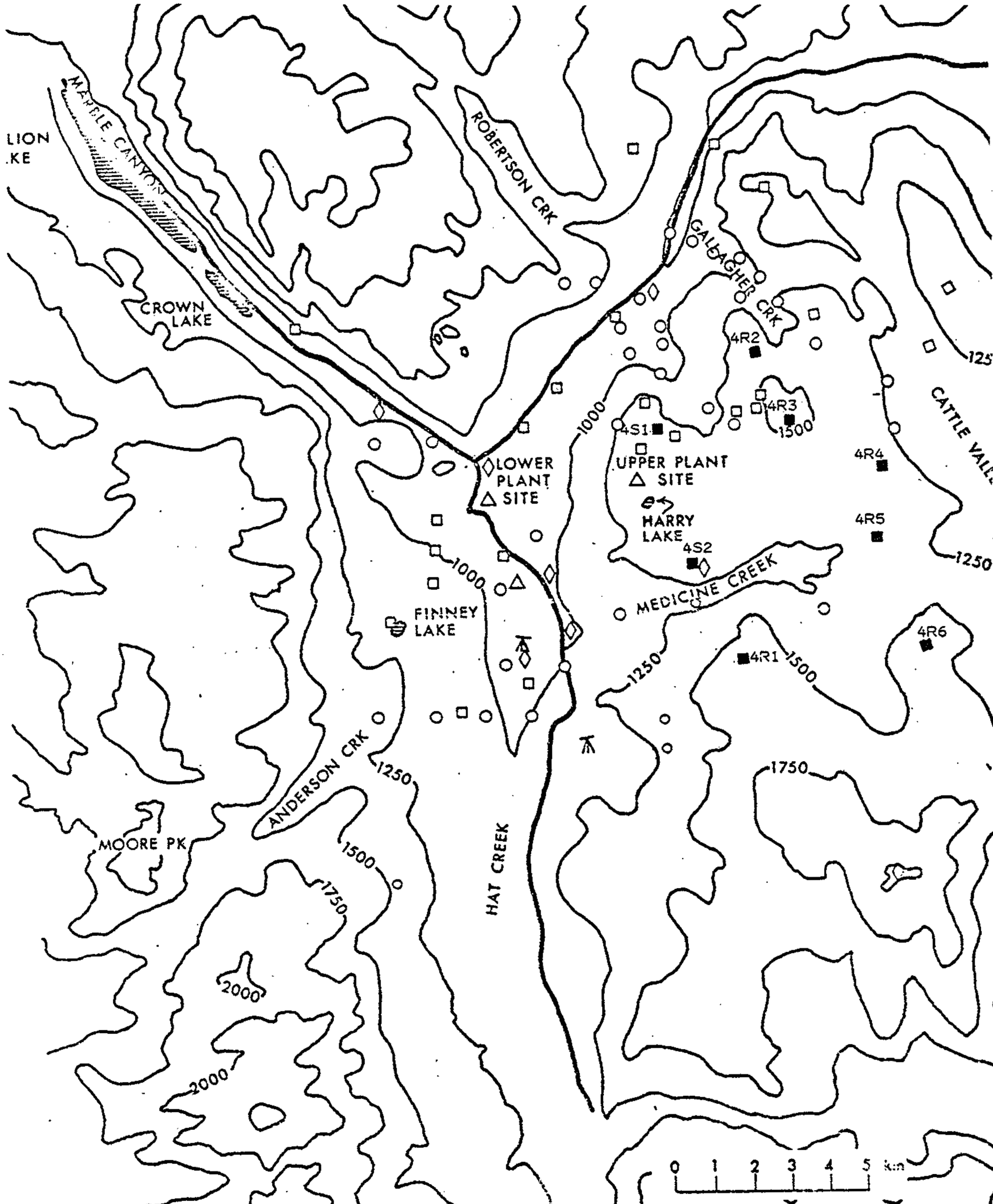


Figure 4.4-5 Location of surface SF_6 samplers for Test 4.

Table 4.4-2 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On	Time Off (PST)	Sampling Time (min)	Ambient	NTP
4R1	7.6	1490	1100	1208	78	7778	8711
			1208	1345	97	23984	26862
4R2	8.0	1500	1000	1213	73	23860	26723
			1213	1351	98	2862	3205
4R3	8.0	1585	1100	1216	76	22208	24873
			1216	1357	101	4796	5372
4R4	10.3	1370	1100	1219	79	7374	8259
			1219	1403	114	12092	13543
4R5	10.1	1400	1105	1223	78	22088	24739
			1223	1407	104	18054	20220
4R6	12.0	1650	1110	1226	76	36234	40582
			1226	1411	105	25312	28349
4S1	4.8	1375	1040	1100	20	80	90
			1100	1130	30	80	90
			1130	1200	Malf.	-	-
4S2	5.5	1350	1100	1130	30	806	903
			1130	1200	30	1130	1266
			1200	1230	30	0	0
			1230	1300	30	160	179
			1300	1330	30	40	45

indicate a Pasquill "D" stability with rapid mixing in the lower layers caused by the winds and rough terrain. Assuming that the plume centerline impacted at site 4R6, 12 km downwind, the stability would have to be a Pasquill "G" type for the estimated centerline concentration to be equal to the concentration measured at the site. This disparity leads to two possible conclusions: either the tracer data are in error, or some mechanism peculiar to that site brought the plume to the ground in a highly concentrated form.

Regarding possible tracer data errors, a check was made to determine if there was any evidence of contamination. At least two background samples were taken prior to the release and they gave zero concentrations. In addition, several samples taken during the test were also zero, which eliminates the possibility of any widespread contamination. As to the possibility of high concentration plume impact, the constant volume balloon observations give evidence of the presence of microscale meteorological phenomena during this test which suppressed the vertical rise of the balloons along the rising terrain to the east. This process may have contributed to the persistent high values observed during this test. However, the magnitude of this impact still makes the validity of the maximum values suspect, and suggests that some type of sampling contamination may have occurred.

4.5 Test Number Five, March 26, 1976

Test number 5 was conducted from 1350 to 1438 PST to simulate the plume impact from strong southerly flow at the upper site. The flow was 10-12 m/s from 205° to 215° during the mid-day release. A constant volume balloon released from near the lower site at 1050 PST eventually struck the ground near its float level just north of Robertson Creek, about 8 km north of the plant site. Two other constant volume balloons were launched during and just following the tracer release and showed strong southerly flow aloft. The tracks of these balloons are shown in Figures 4.5-1, 4.5-2, and 4.5-3.

An examination of the tracer concentrations measured by a network of samplers revealed the strong possibility of widespread contamination. Consequently, the data from Test 5 will not be reported or discussed in this report.

The actual meteorological conditions during release number 5 are similar to those during Tests 2 and 3. The results of Tests 2 and 3 revealed no significant impact. Because of the similarity, that result can reasonably be applied to test number 5.

4.6 Test Number Six, July 31, 1976

This tracer release was conducted over the upper plant site at an altitude of 1770 m MSL during the morning of July 31. The meteorological conditions appeared favorable for examining the interaction of a slightly stable plume with the complex terrain to the north and east. A stack height of 183 m was assumed with 215 m plume rise. Due to a mechanical malfunction, the total amount of SF_6 released was about 10% the expected amount.

4.6.1 Synoptic Setting for Test 6. Surface weather features consisted of weak low pressure over much of British Columbia, Washington, and Oregon. A continental polar high pressure system was located over central Canada. At 500 mb, a closed low pressure system was located over southern British Columbia. The trough of low pressure associated with the closed low extended southwestward over the Pacific Ocean. High pressure was developing over the Yukon Territory at 500 mb. These factors produced a southerly to southwesterly gradient flow over the test area.

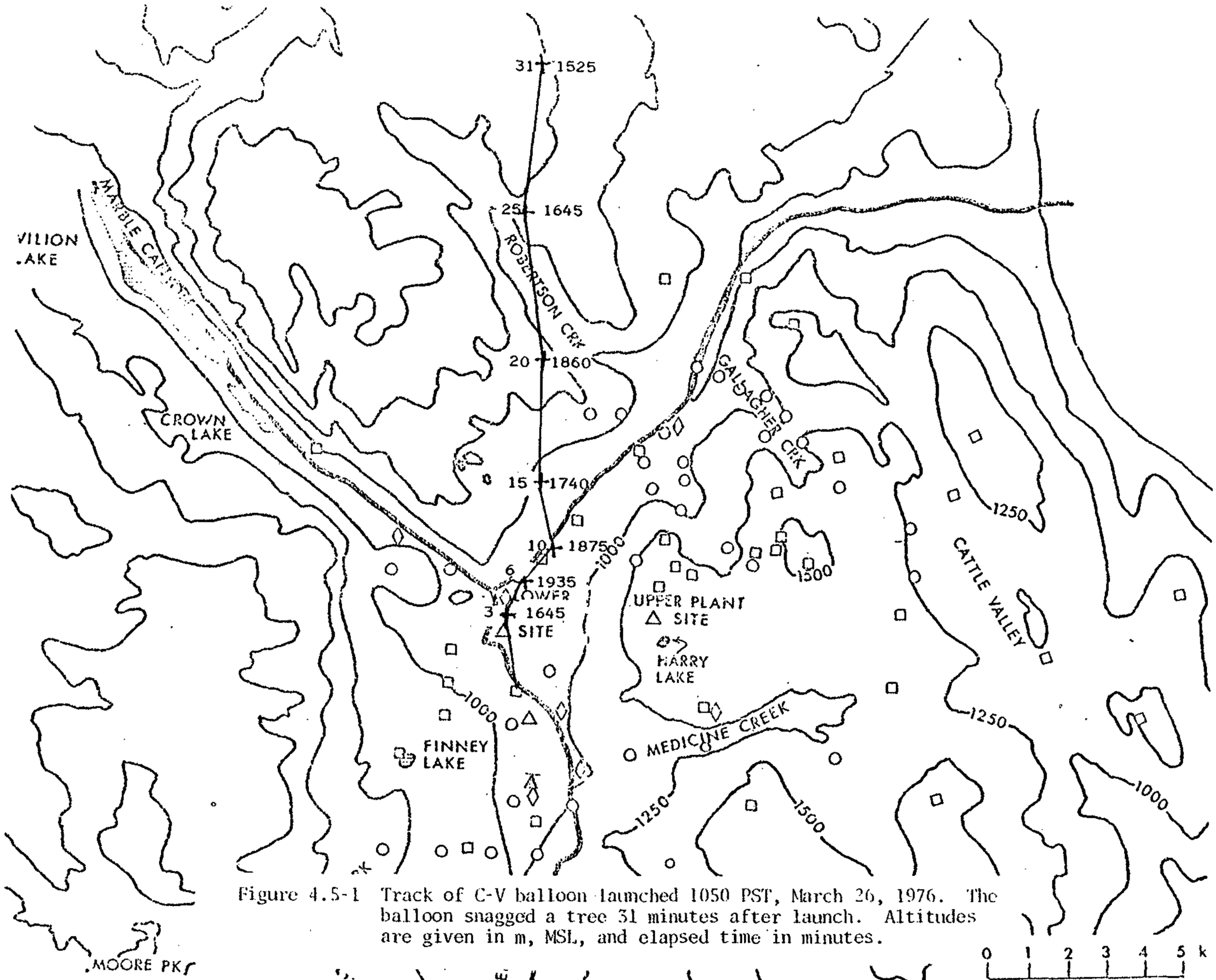


Figure 4.5-1 Track of C-V balloon launched 1050 PST, March 26, 1976. The balloon snagged a tree 31 minutes after launch. Altitudes are given in m, MSL, and elapsed time in minutes.

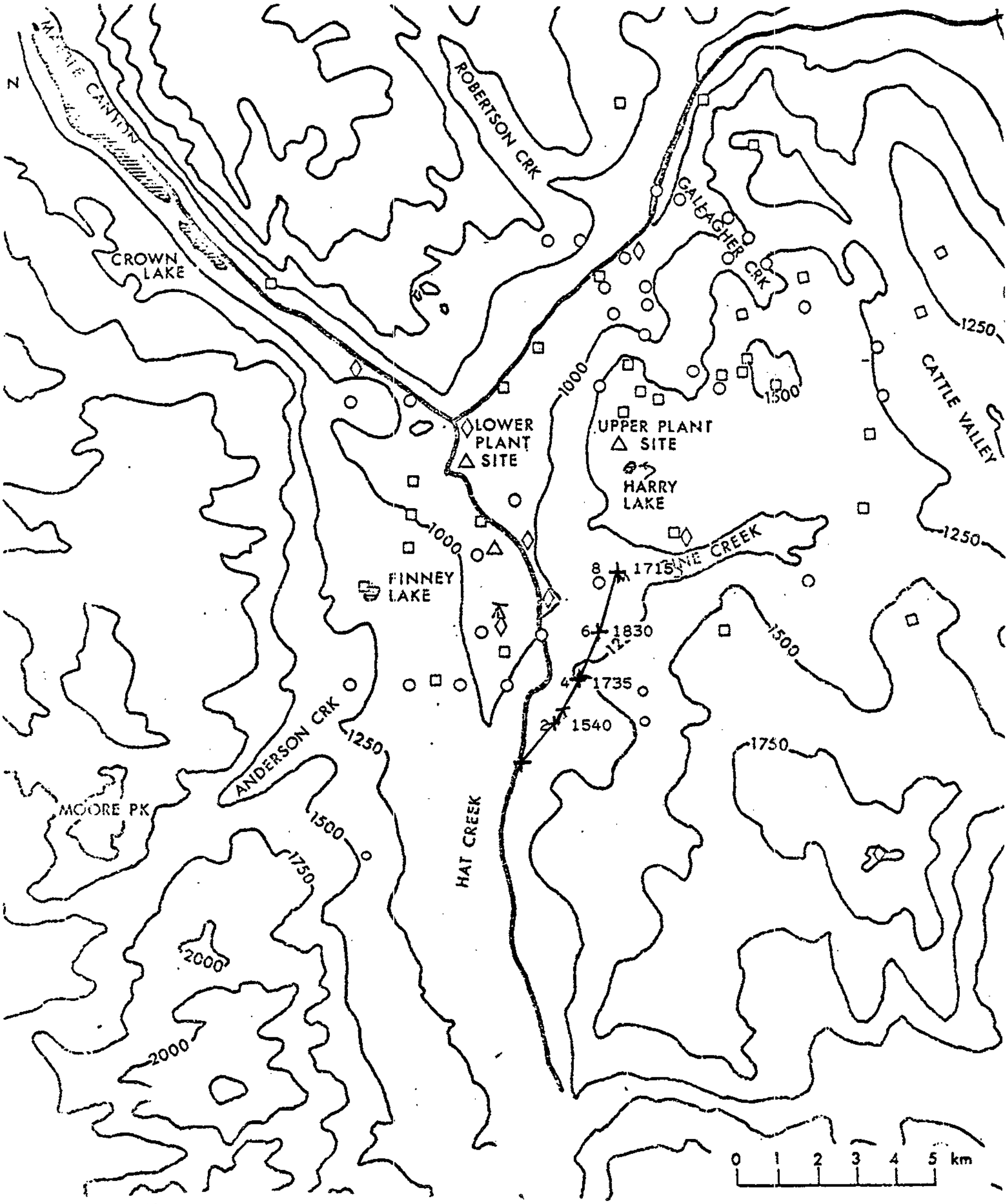


Figure 4.5-2 Track of C-V balloon launched 1425 PST, March 26, 1976. Altitudes are given in m, MSL, and elapsed time in minutes.

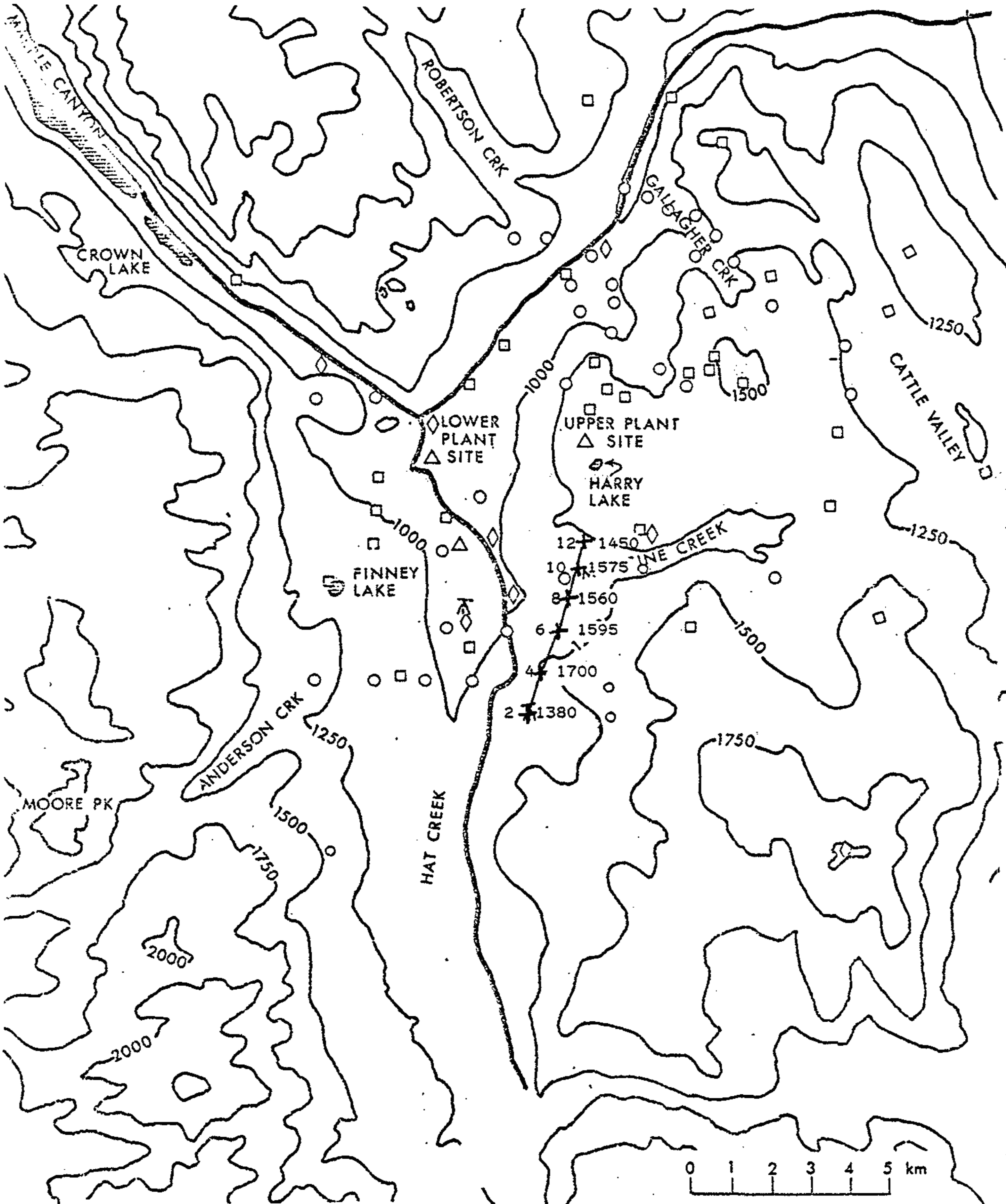


Figure 4.5-3 Track of C-V balloon launched 1445 PST, March 26, 1976. Altitudes are given in m, MSL, and elapsed time in minutes.

Clouds due to the low pressure system were broken stratocumulus with scud over some of the hills near the test area.

Surface and 700-mb maps are shown in Figure 4.6-1.

4.6.2 Meteorological Parameters for Test 6. Meteorological parameters measured during this test include temperature lapse rates, winds aloft, and at the surface. Temperature soundings were made by minisonde, tethered sonde, and by the NAWC tracer aircraft. Winds aloft were determined by double-tracked pilot balloon ascensions. Surface winds were monitored by the B. C. Hydro remote station network.

The temperature soundings taken in the project area during this test are presented in Figure 4.6-2. The early morning soundings show a weak surface inversion with slightly stable conditions extending to near plume altitude where a thin isothermal layer was found. The surface inversion was dissipated by heating and disappeared by 0800 PST. Slightly stable conditions persisted at plume height until late in the evening. Two aircraft soundings (abbreviated "TAC" in figures), taken in the Hat Creek Valley at 0550 and 0735 PST, indicate slightly stable conditions extended from plume altitude to the surface, where a weak radiation inversion was found.

The surface wind data for Test 6 is given in Volume II Field Data. The measurements indicate the low lying sites experienced a diurnal pattern with the switch from down- to up-valley flow occurring at about 0730 PST. Wind speeds were greatest during up-valley flow, though average speeds did not exceed 2.5 m/s. Elevated stations experienced stronger west to southwest winds and showed little change during the test. Mean wind speeds ranged to 5.6 m/s.

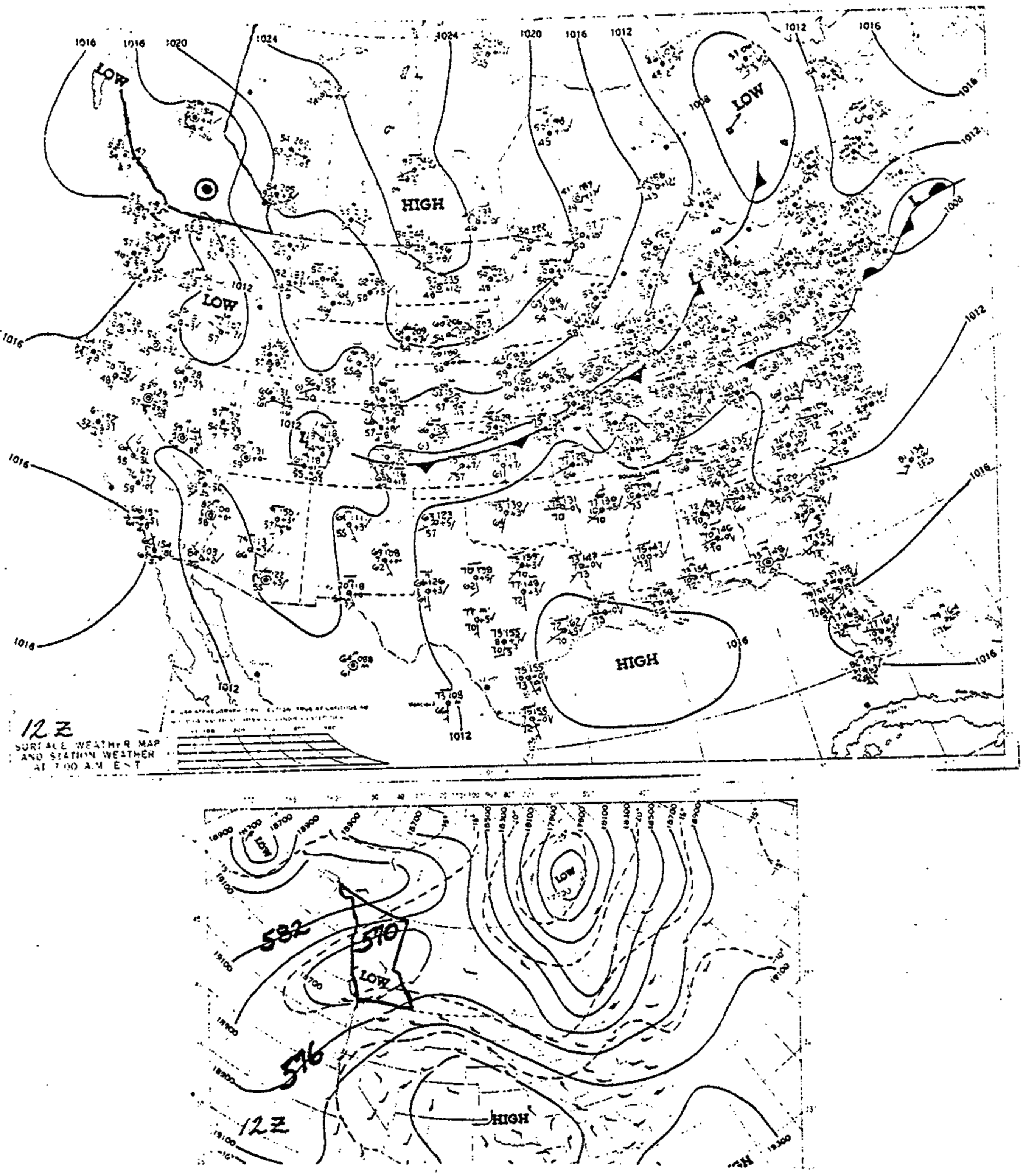


Figure 4.6-1 Surface and 500 mb maps for Test 6, July 31, 1976, 0400 PST.

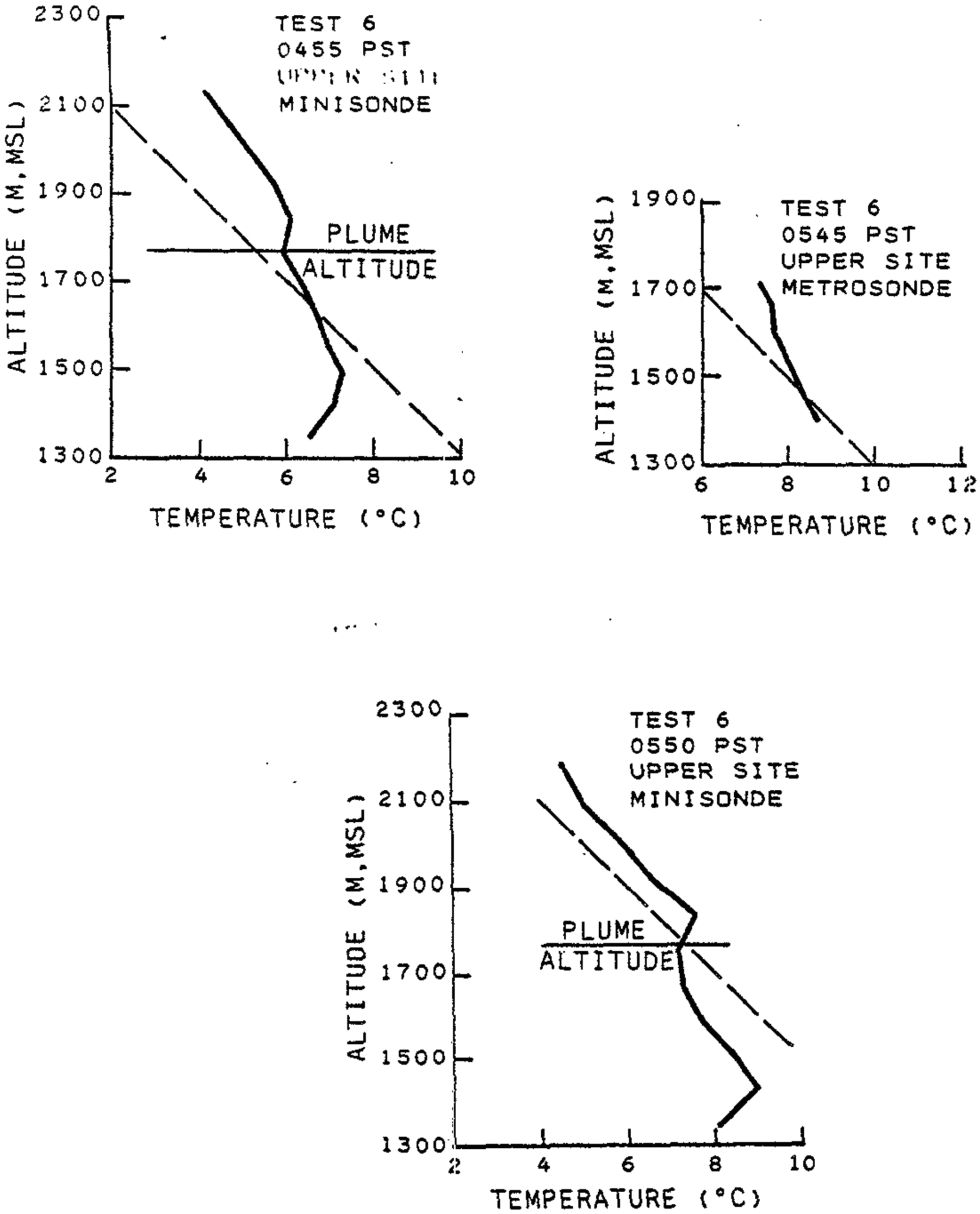
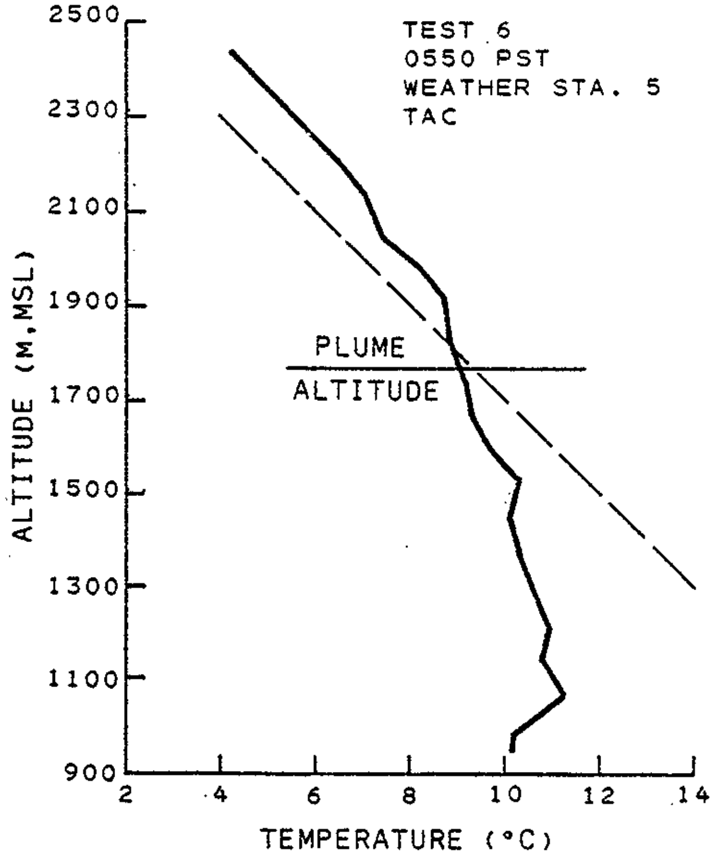


Figure 4.6-2 Vertical temperature profiles for Test 6.



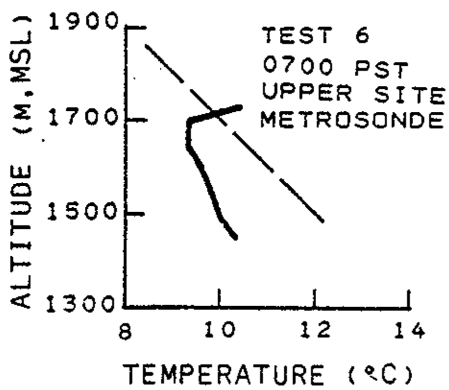


Figure 4.6-2 (Cont'd).

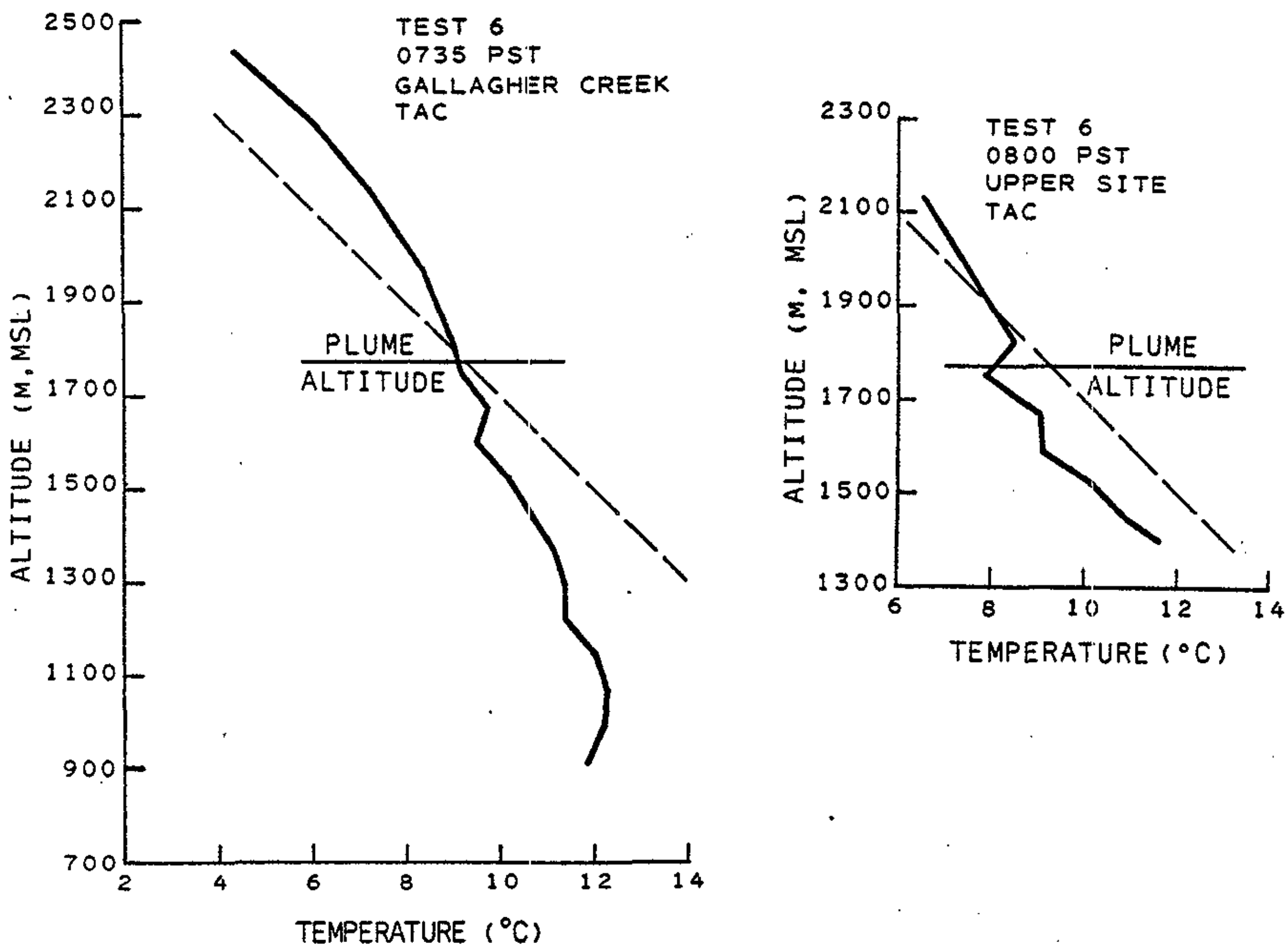


Figure 4.6-2 (Cont'd).

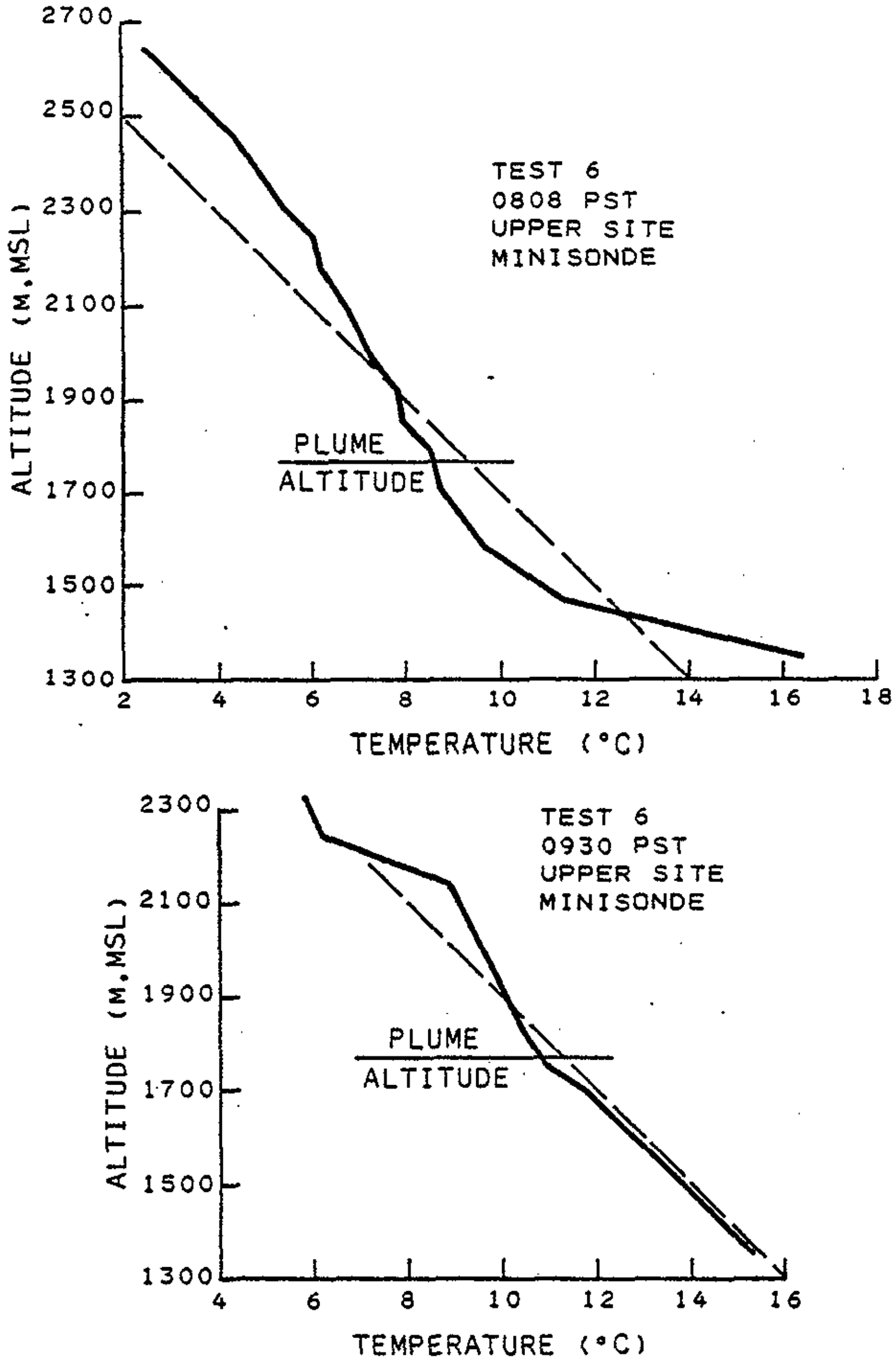


Figure 4.6-2 (Cont'd).

The winds aloft measurements were made from the upper plant site. The wind direction and wind speed time sections are shown in Figures 4.6-3 and 4.6-4, respectively. These show that wind direction at plume altitude was apparently not affected by the diurnal circulation below, though wind speeds show a significant drop associated with down- to up-valley change in flow.

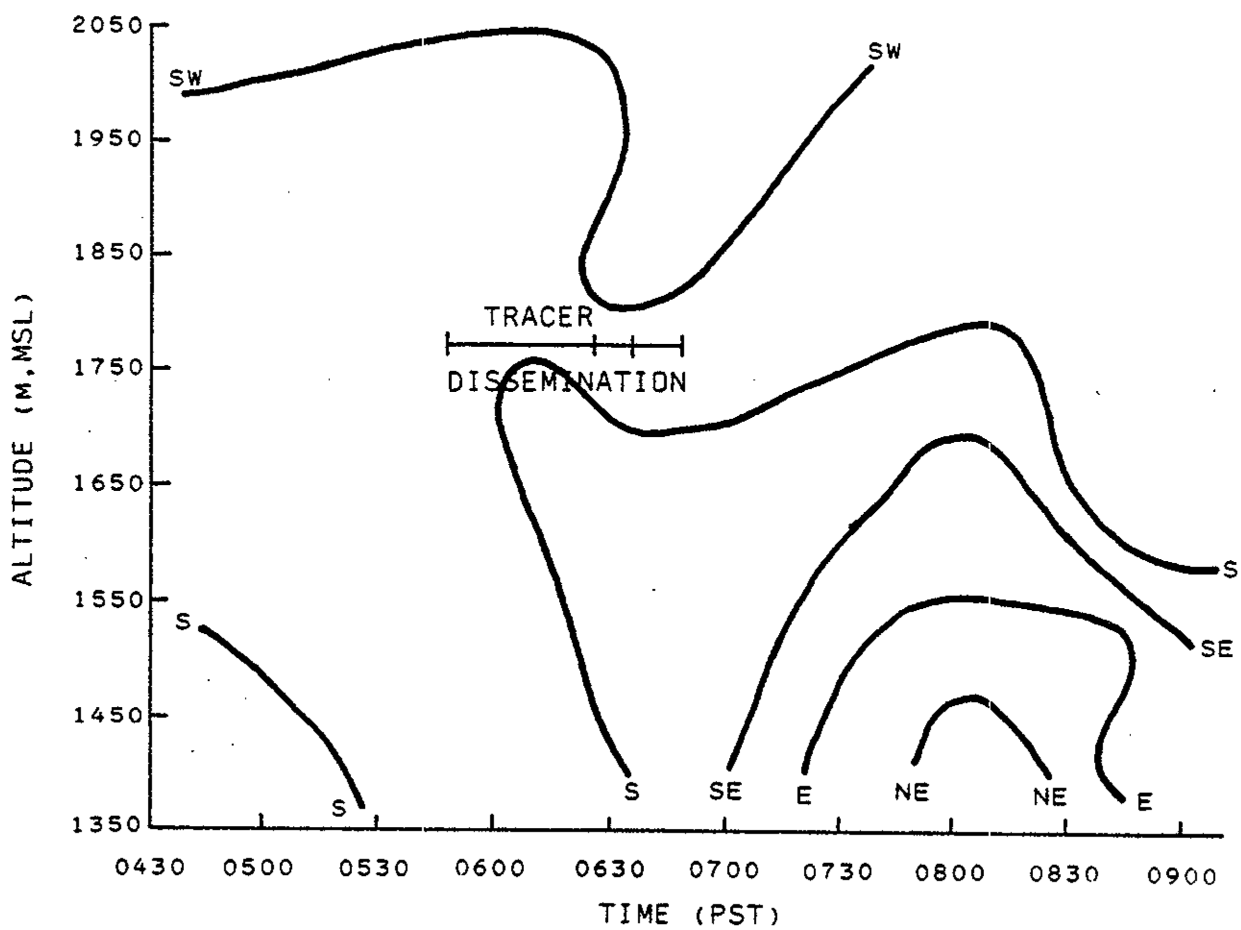


Figure 4.6-3 A time vs. altitude display of wind direction aloft measured during Test 6.

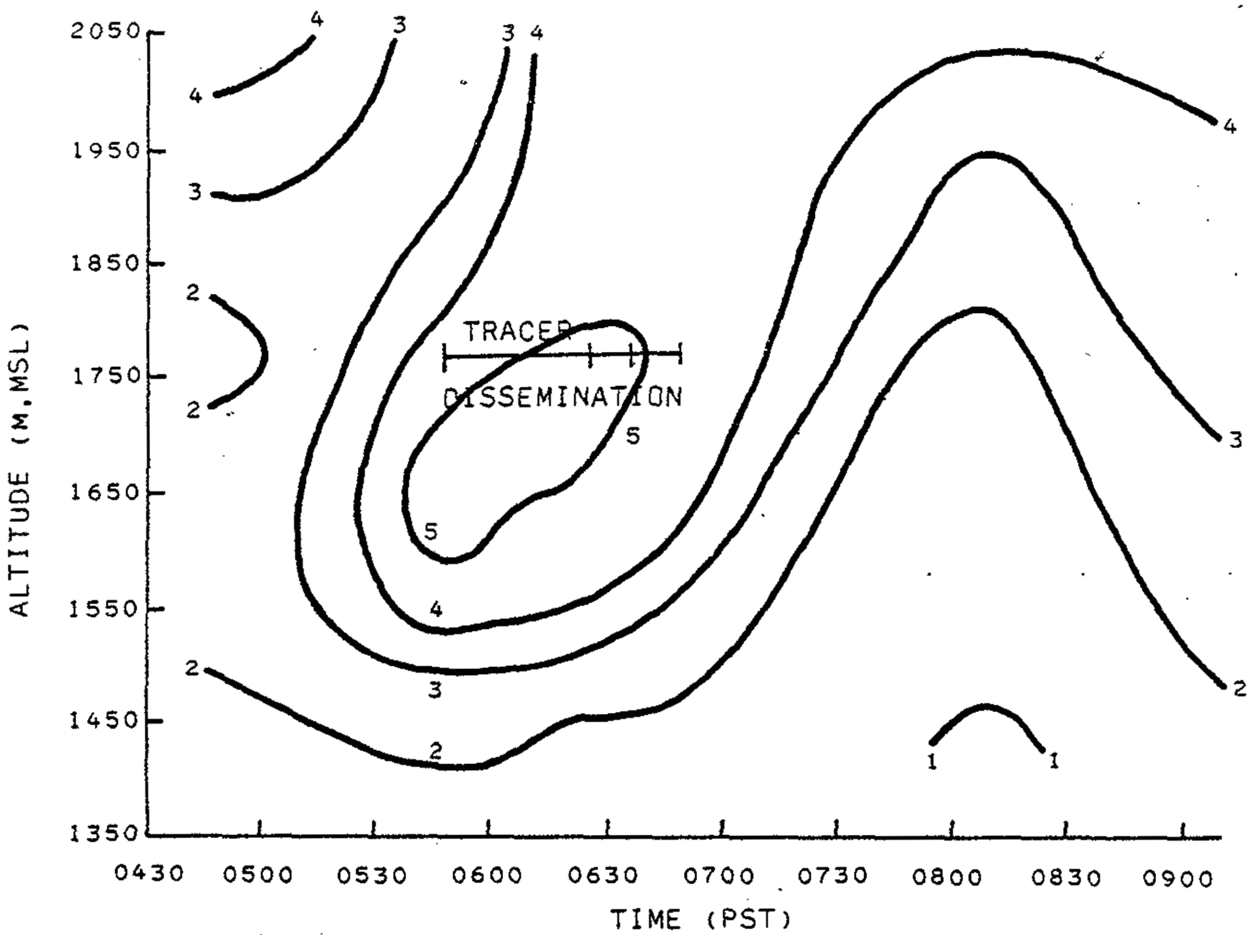


Figure 4.6-4 A time vs. altitude display of wind speeds aloft measured during Test 6. Wind speeds are given in m/s.

4.6.3 Tracer Dissemination, Test 6. The release parameters for Test 6 are contained in Table 4.6-1, below.

4.6.4 Visual and Photographic Observations. The oil-fog plume was transported to the northeast throughout the test. Figure 4.6-5 shows the plume 13 minutes after the release began. As the plume passed over the small valley 3 km from the release site, it apparently rose slightly. General northeastward transport continued during the next half-hour, but the plume centerline

Figure 4.6-5 Test 6 tracer release looking southeast towards the upper site.

Figure 4.6-6 Test 6 tracer plume. Photo taken looking southwest, up Lower Hat Creek Valley.

Table 4.6-1 Duration and source strength of tracer release number 6.

Location: Upper Site
Altitude: 1770 m MSL
Simultate Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0551	0651	~ 1800	~ 0.50
Oil Fog (1)	0551	0627	109800	50.8
Oil Fog (2)	0636	0651	N/A	N/A

gradually drifted northward until it was directly over Lower Hat Creek Valley (Figure 4.6-6). By 0700 PST, the plume's leading edge was over the Bonaparte River Valley near Carquile. After that, transport was slightly more to the north. Figure 4.6-7 shows the faint remnants of the plume north of Scotty Creek at 0755 PST and about 30 to 35 km northeast of the release site.

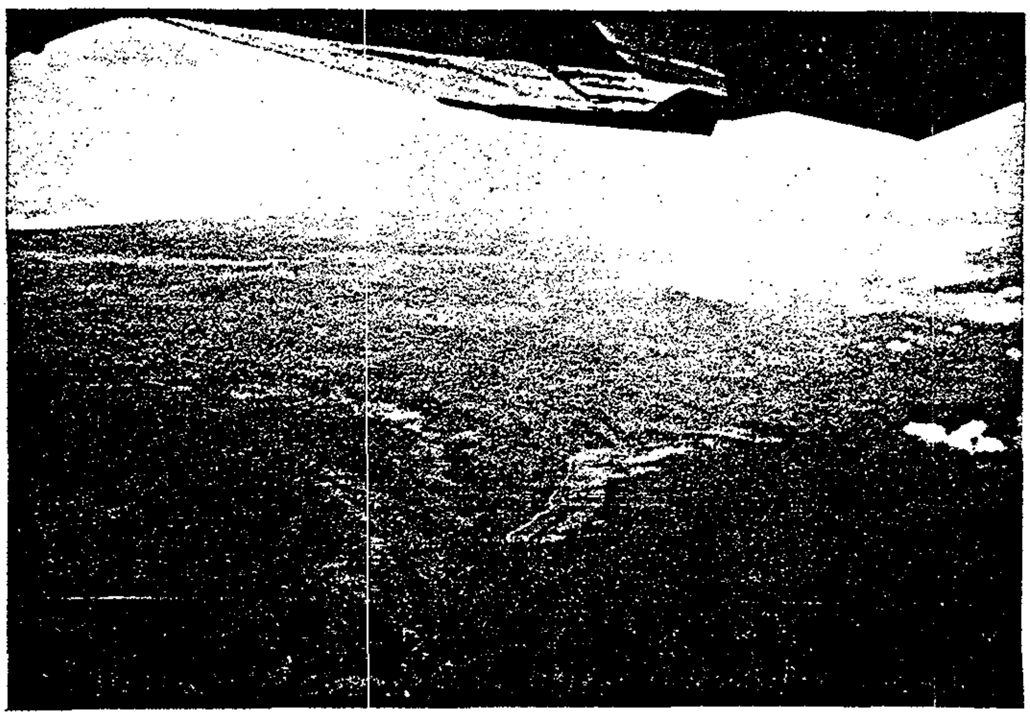


Figure 4.6-7 Test 6 tracer plume over Scotty Creek, view looking northeast.

The average plume speed during the two hours of observation was 4.1 m/s. The speed of the leading edge of the plume ranged from 2.5 m/s to 5.9 m/s, the highest during the first 15 minutes of the test.

Plume locations at selected times during the test are shown in Figure 4.6-8.

4.6.5 Oil-Fog Measurements. Four sets of crosswind passes were made during Test 6 at locations shown in Figure 4.6-9. The first, 5.3 km from the release, yielded a maximum concentration equivalent to 9773 μgm^{-3} at 1770 m MSL. A plot of maximum concentration vs. altitude for this set and a plot of concentration vs. distance for the 1770 m pass are given in Figure 4.6-10. Because the trailing edge of the oil-fog cloud was approaching, only three passes were made at this location. The values of σ_y and σ_z, and $\frac{X\bar{u}}{Q}$ have been calculated from the data available and appear in Figures 4.6-11 and 4.6-12. The first shows that the measurements of σ_y and σ_z indicate and E-F (stable) type plume geometry when compared with the standard curves. The value of $\frac{X\bar{u}}{Q}$, on the other hand, indicates a D-E (slightly stable) rate of dilution.

The second set of passes certainly missed the main portion of the plume which apparently was at higher altitudes. Because of this, only a value for σ_y could be determined. This is plotted in Figure 4.6-11 and, as before, indicates a dimension associated with E-F stability. Figure 4.6-13 presents the horizontal and vertical plume distributions measured here.

The third set of passes were made just north of the mouth of Hat Creek Valley. Five passes were made here at altitudes between 1675 and 1800 m MSL. The peak concentration was found at 1770 m MSL and was equivalent to 6413 μgm^{-3}. A plot of altitude vs. maximum concentration for the set together with the distance vs.

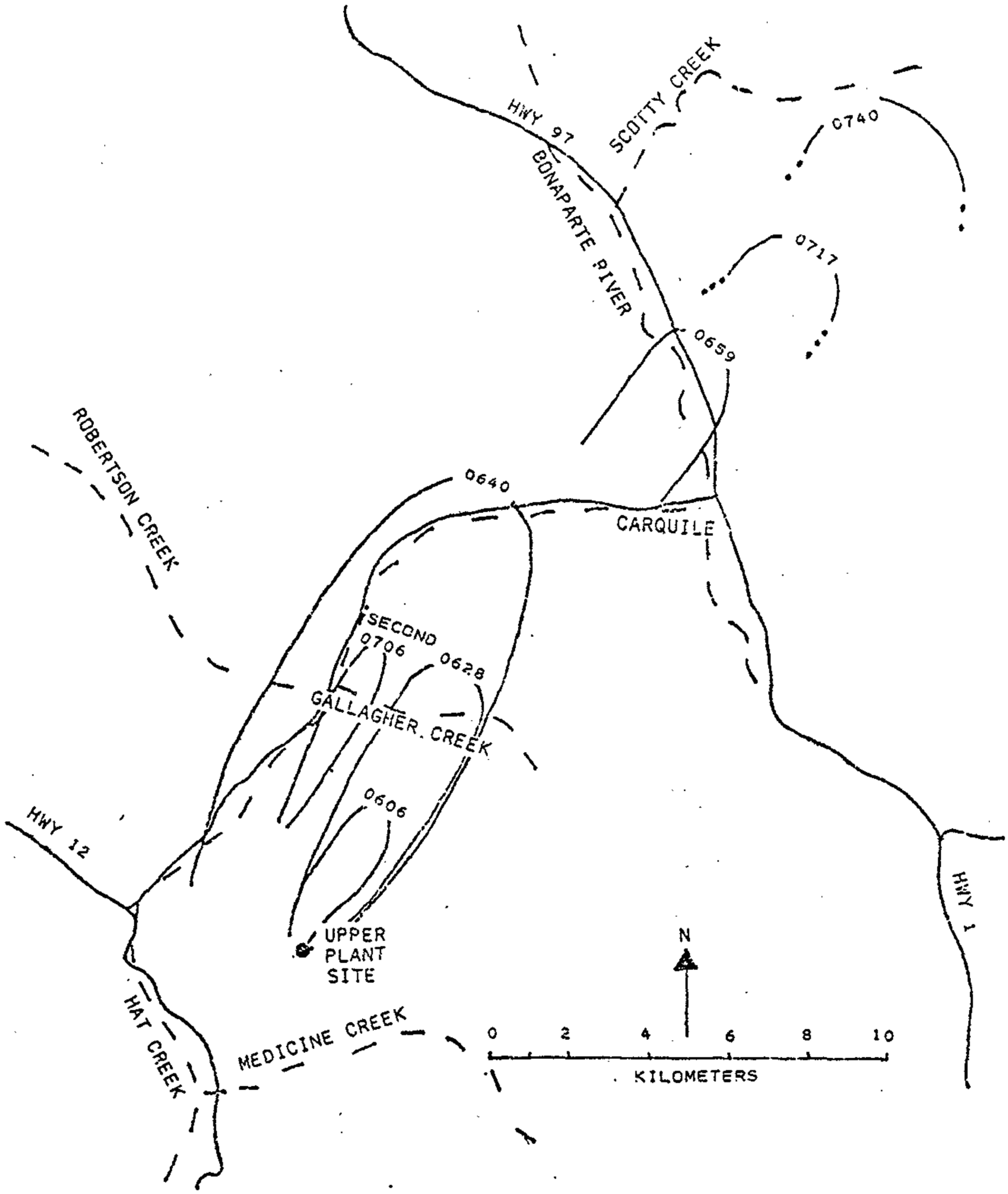


Figure 4.6-8 Plume outlines, Test 6.

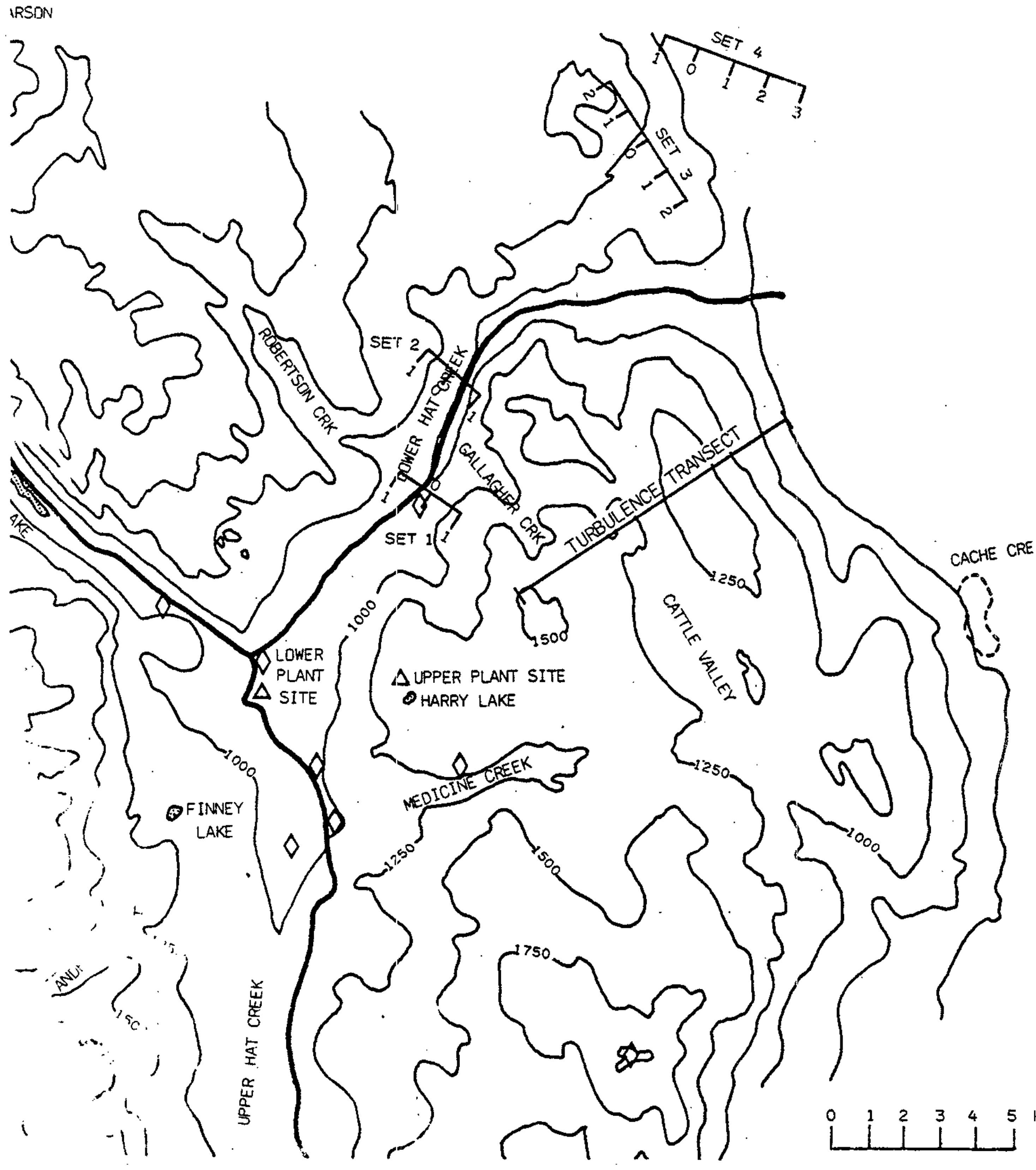


Figure 4 Locations of oil fog crosswinds and turbulence transects, Test 6.

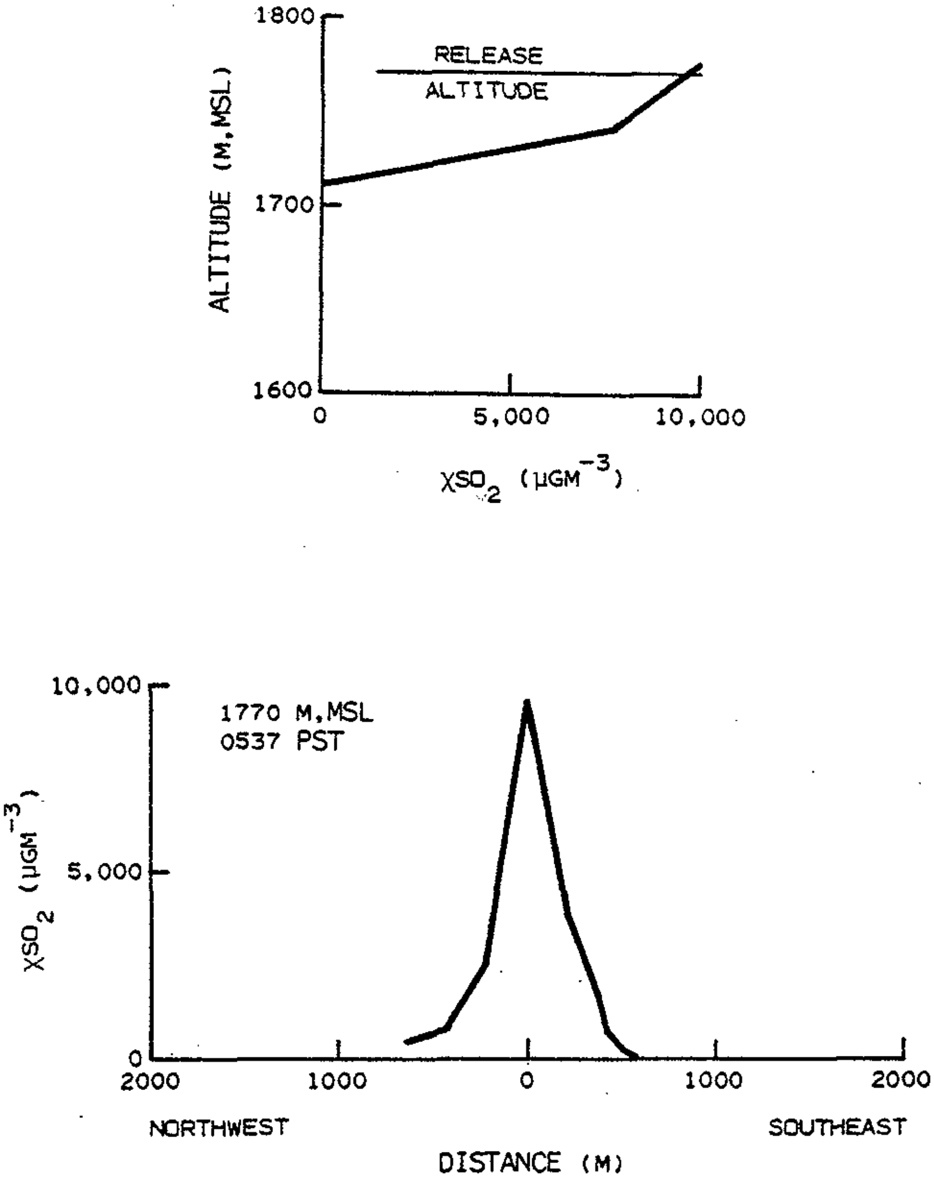


Figure 4.6-10 Horizontal and vertical plume centerline distributions from oil-fog data, Test 6, Set 1.

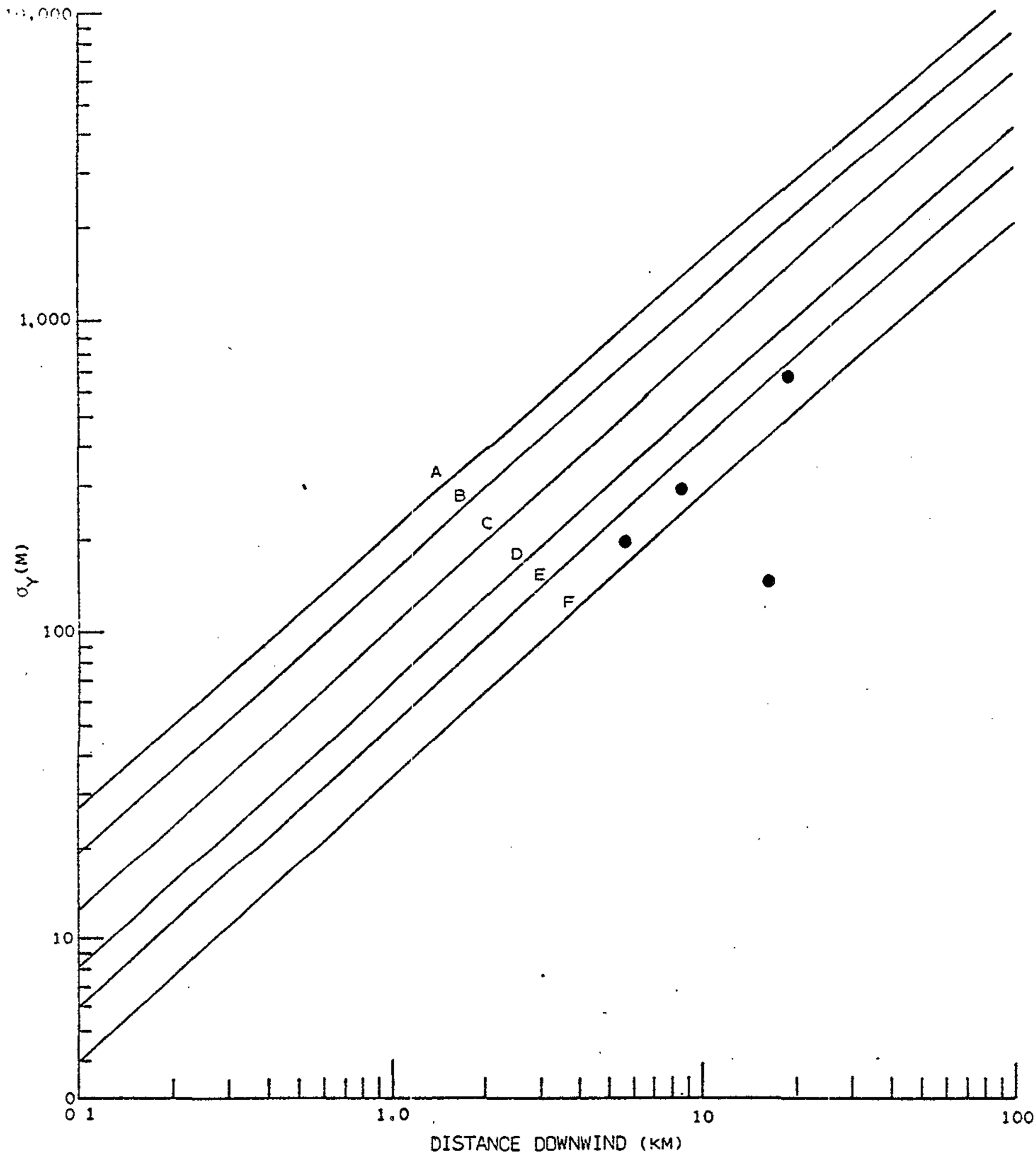


Figure 4.6-11 Measured horizontal and vertical dispersion coefficients vs. distance, Test 6.

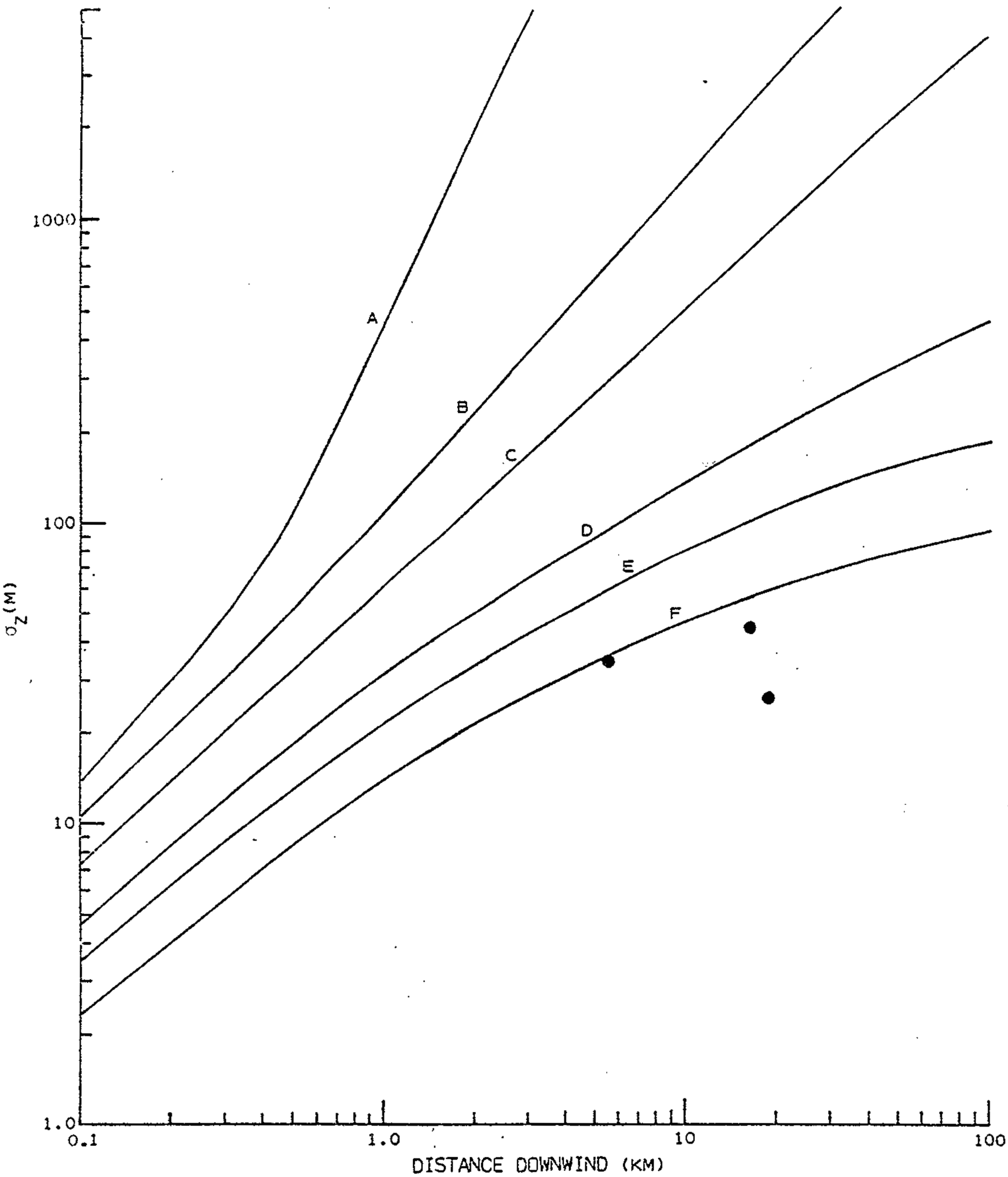


Figure 4.6-11 (Cont'd).

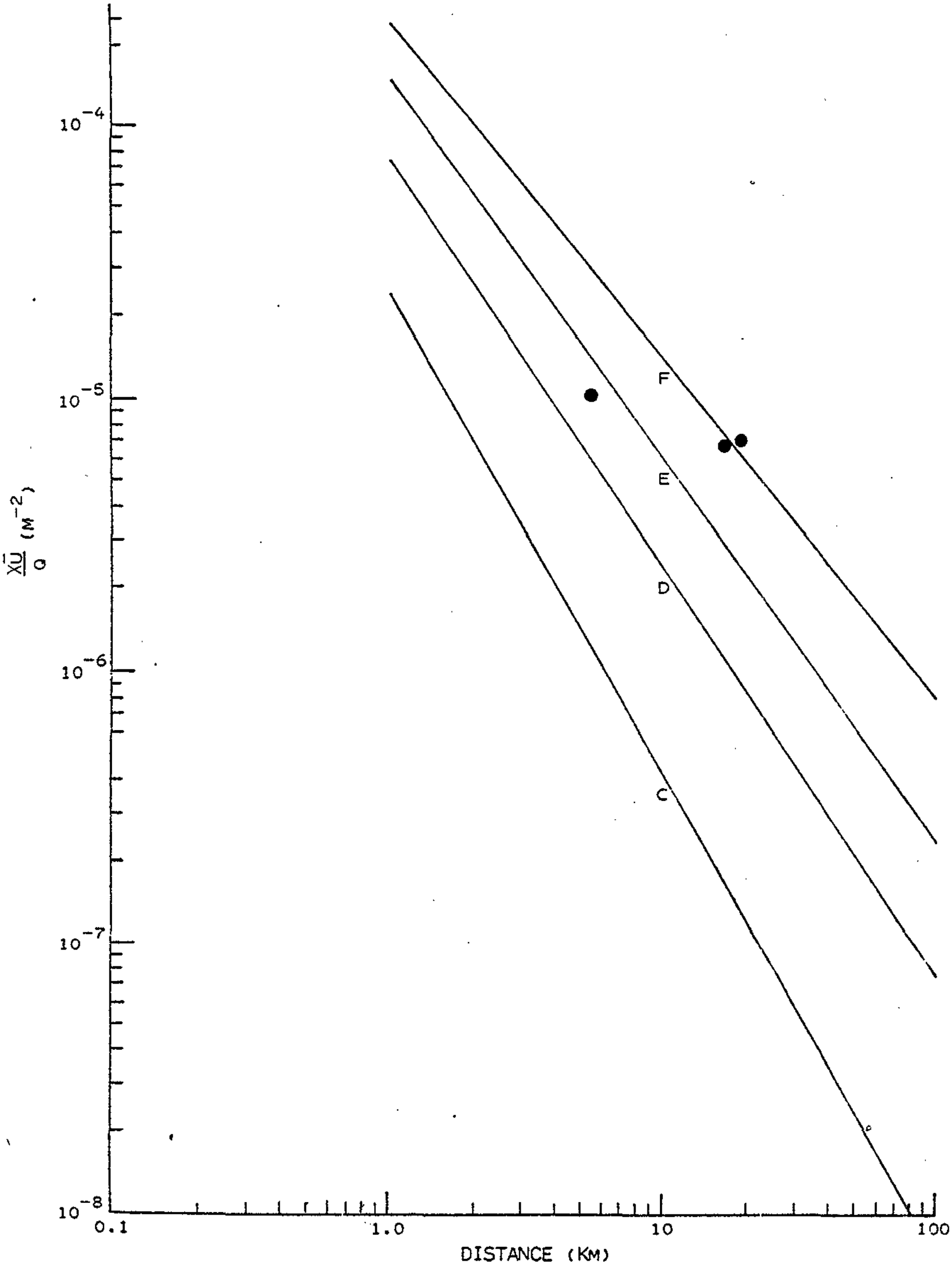


Figure 4.6-12 Normalized centerline concentrations, $\frac{\chi \bar{u}}{Q}$, vs. distance, Test 6.

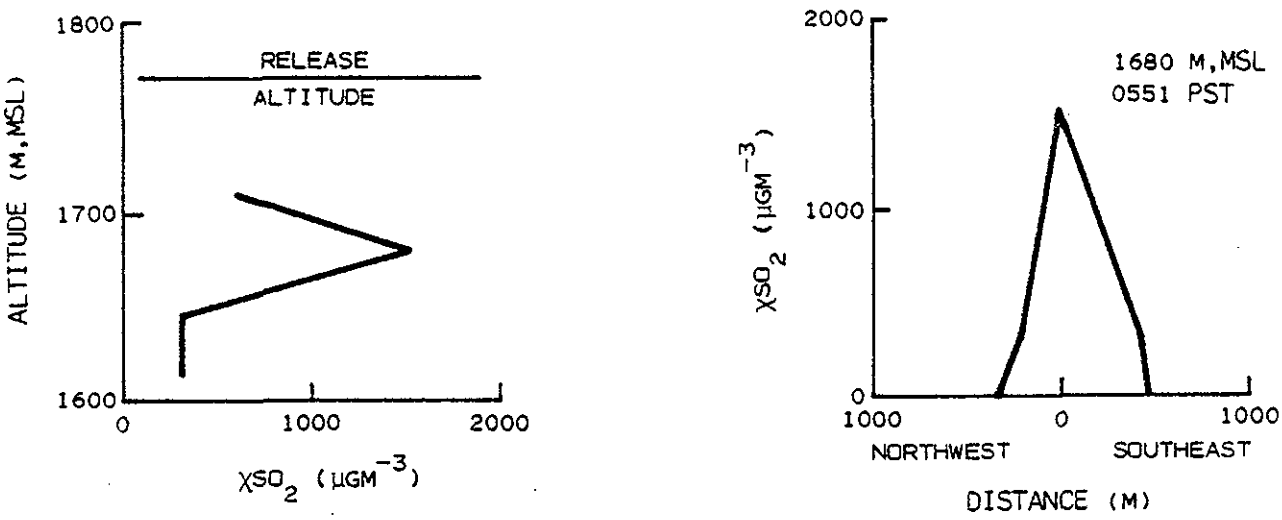


Figure 4.6-13 Horizontal and vertical concentration distributions from oil-fog data, Test 6, Set 2.

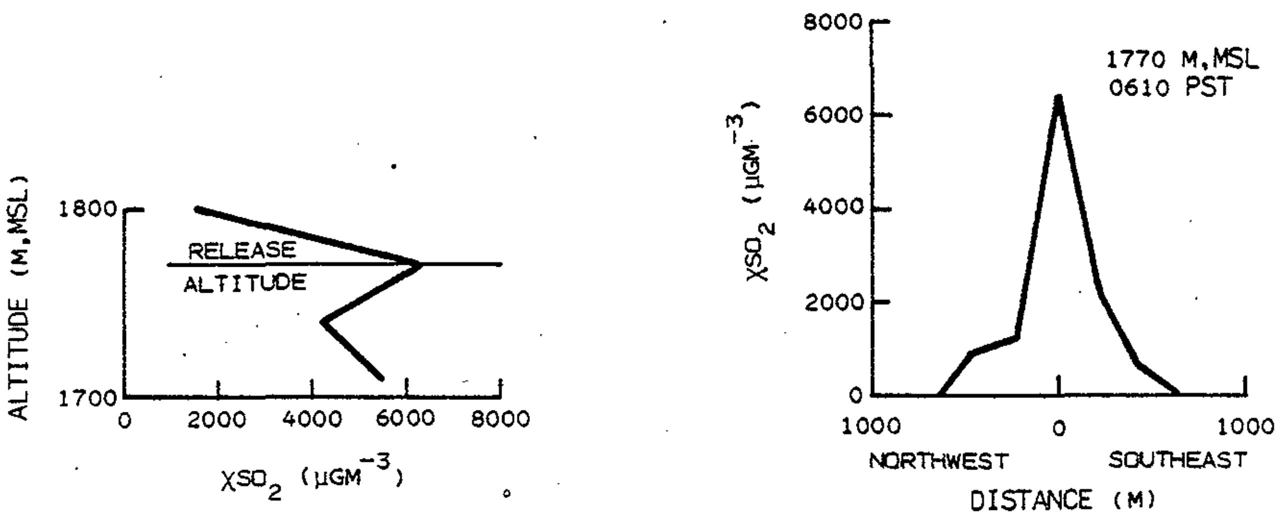


Figure 4.6-14 Horizontal and vertical centerline distributions from oil-fog data, Test 6, Set 3.

concentration plot for 1770 m pass are given in Figure 4.6-14. It is of interest to note that the plume centerline was still found at or above release altitude, though terrain elevations had dropped. The values of σ_y, σ_z, $\frac{\chi\bar{u}}{Q}$ are plotted on Figures 4.6-11 and 4.6-12. The value of σ_y is unaccountably low and probably not representative of the plume as a whole. The value of $\frac{\chi\bar{u}}{Q}$ falls close to that for F type stability.

The fourth set of measurements was made 19 km from the release over the Bonaparte Valley as shown in Figure 4.6-9. Passes were made at four altitudes between 1645 and 1740 m MSL. The maximum concentration, found at 1710 m MSL, was equivalent to 7940 $\mu g m^{-3}$. A concentration vs. distance plot for that pass and the altitude vs. maximum concentration for the entire set are presented in Figure 4.6-15. These measurements suggest that, as the plume was transported over the Bonaparte River Valley, the plume centerline dropped about 60 m without any large increase in vertical spread. This behavior would indicate a certain degree of stratification in the flow though lapse conditions appear to be only slightly stable.

Measurements of σ_y, σ_z, and $\frac{\chi\bar{u}}{Q}$ for these passes are shown in Figures 4.6-11 and 4.6-12. The value of σ_y continues to indicate E-F type behavior. The value of σ_z has evidently decreased, probably reflecting the coarseness of the sampling passes with respect to the thickness of the plume. The value of $\frac{\chi\bar{u}}{Q}$ indicates continued very slow dilution.

4.6.6 <u>Aerial SF_6 Measurements</u>. Thirteen aerial SF_6 samples were taken by helicopter at locations shown in Figure 4.6-16. Table 4.6-2 supplies sampling data. None received measurable SF_6, apparently due to the low tracer source strength and the lack of downward transport.

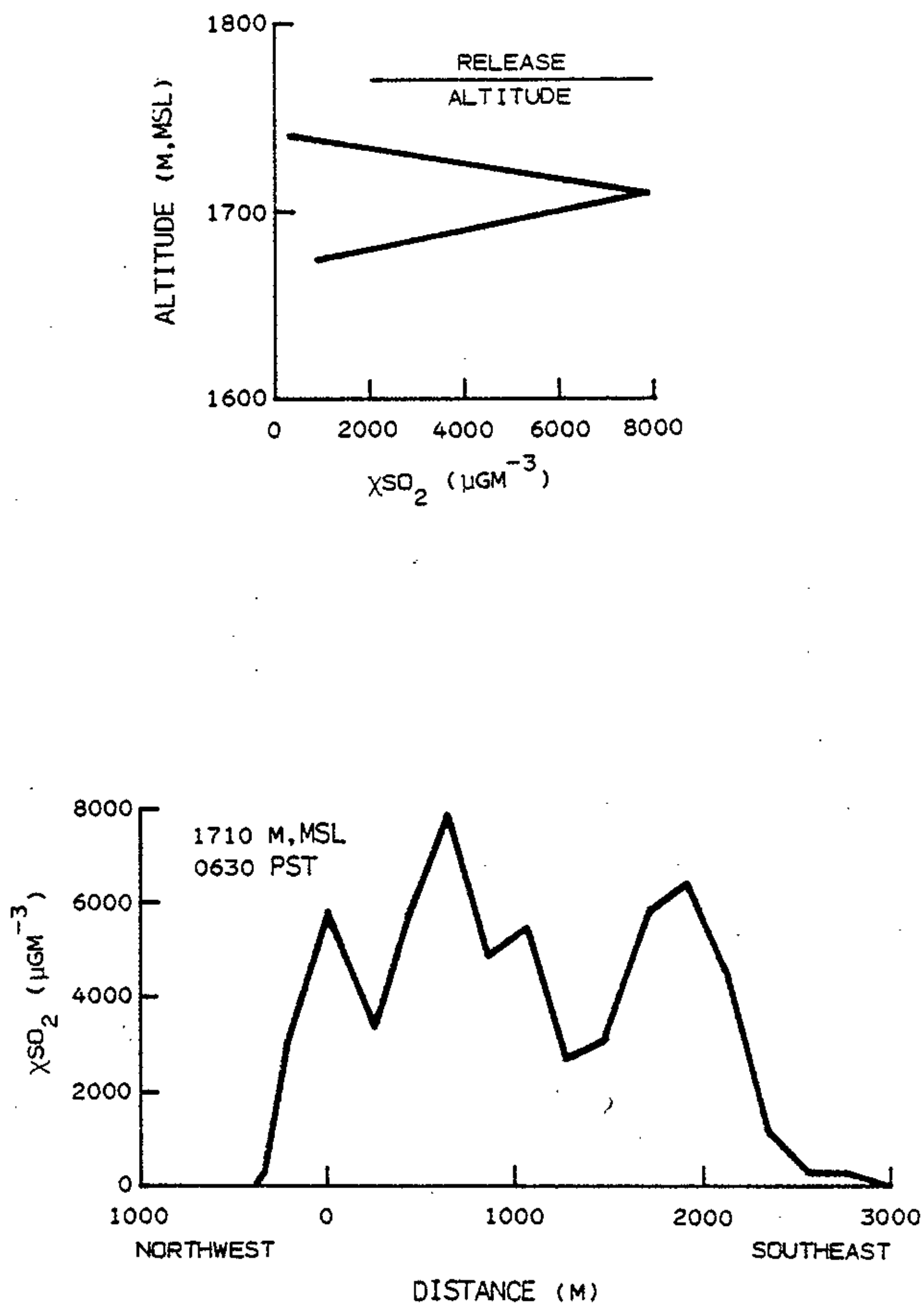


Figure 4.6-15 Horizontal and vertical centerline distributions from oil-fog data, Test 6, Set 4.

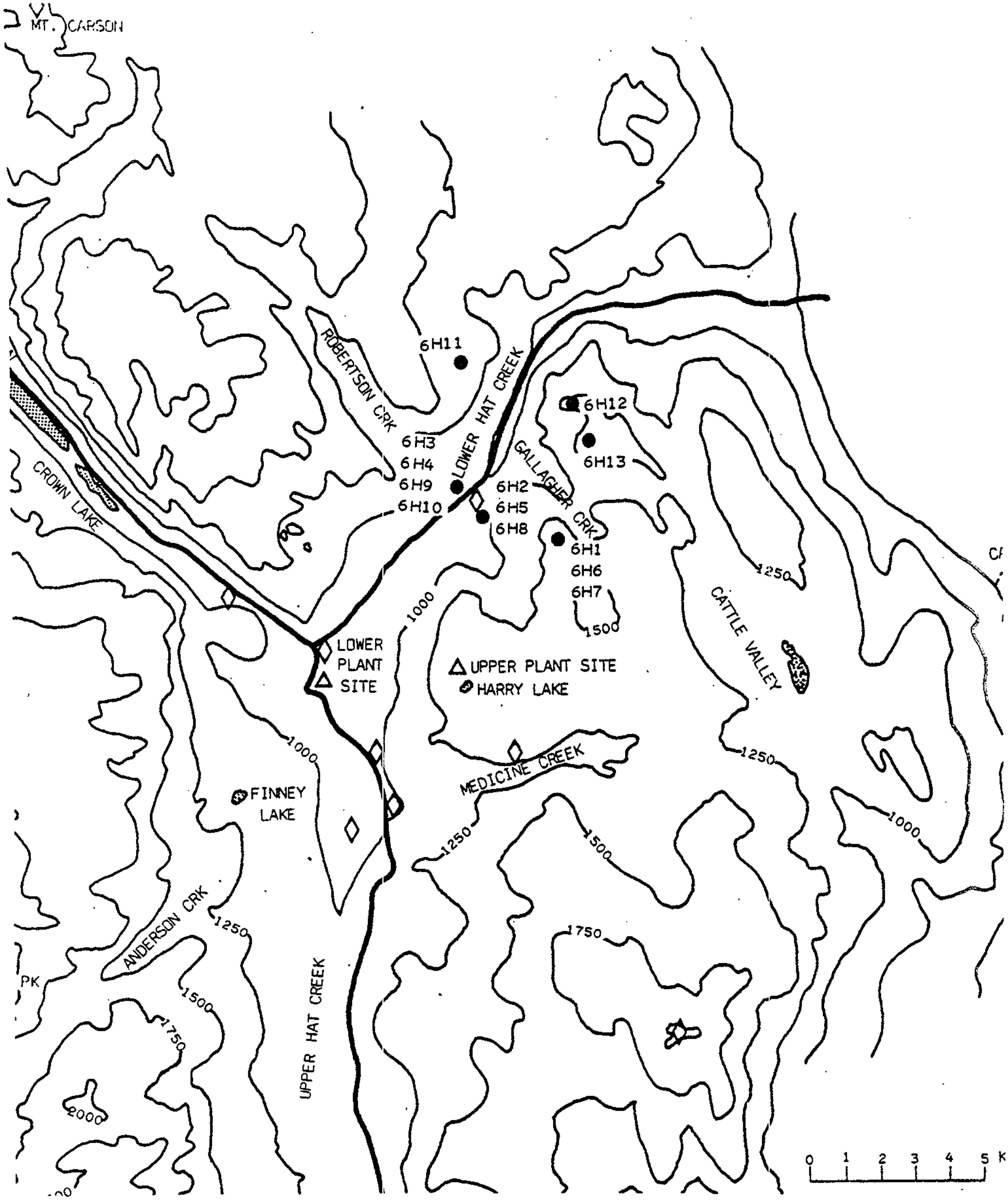


Figure 4.6-16 Locations of aerial SF_6 samples, Test 6.

Table 4.6-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	Altitude (m) AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
6H1	4.6	1740	305	0620	1	0	0
6H2	4.8	1740	795	0622	1	0	0
6H3	5.4	1740	945	0624	1	0	0
6H4	5.4	1645	850	0626	1	0	0
6H5	4.8	1645	700	0630	1	0	0
6H6	4.6	1645	210	0632	1	0	0
6H7	4.6	1555	120	0634	1	0	0
6H8	4.8	1555	610	0638	1	0	0
6H9	5.4	1555	760	0640	1	0	0
6H10	5.4	1465	670	0642	1	0	0
6H11	9.4	1465	395	0645	1	0	0
6H12	8.6	1465	215	0650	1	0	0
6H13	8.0	1465	185	0655	1	0	0

4.6.7 Surface SF_6 Measurements. Fifteen surface SF_6 samplers were deployed during the test at distances up to 10 km from the release as shown in Figure 4.6-17. Sampling information is available in Table 4.6-3. Only site 6S7 received measurable SF_6 (at the detectable limit) which measured an equivalent concentration of less than 263 μgm^{-3} between 0745 and 0945.

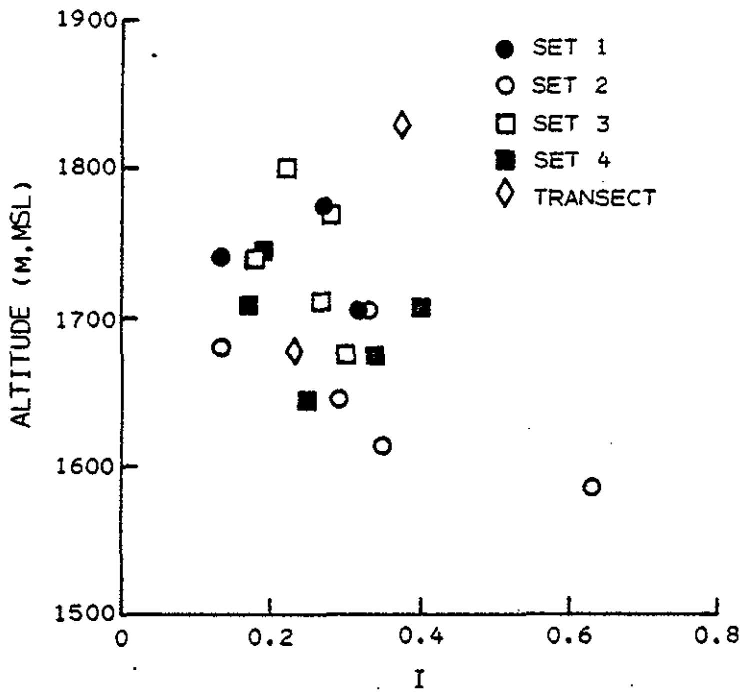
4.6.8 Turbulence Measurements. The turbulence from the oil-fog crosswind patterns together with those from two special turbulence transects are shown in Figure 4.6-18. The data from the oil-fog passes suggest neutral type turbulence environment and show increasing turbulence with height. The two turbulence values from the special transects over the ridges (locations shown in Figure 4.6-9) show the opposite trend and appear to decrease with altitude. Intermittence values were low at all altitudes, suggesting a rather uniform eddy regime, though the lowest altitude passes from set 2 show increasing intermittence, suggesting the existence of occasional disturbances at these less turbulent altitudes.

4.6.9 Summary of Test 6. The Test 6 tracer release was made from the upper plant site at an altitude of 1770 m MSL. A stack height of 183 m was assumed. A mechanical problem caused a 90% reduction in the source strength of SF_6 during dissemination. The plume was released into slightly stable conditions with flow from the south to southwest at 5 m/s. Upon release, the plume moved northeastward, out of the Lower Hat Creek Valley and over the Bonaparte River. Surface and aerial SF_6 measurements showed very little SF_6, indicating that the combination of low source strength and lack of downward mixing resulted in the concentrations which were below the detectable limit, equivalent to about 263 μgm^{-3} in this particular case. Oil-fog measurements suggest that the plume remained near release altitude during transport with little indication of interaction with the terrain, and no

Figure 4.6-17 Location of surface SF_6 samplers, Test 6.

Table 4.6-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	χSO_2 (μgm^{-3})	
						Ambient	NTP
6S4	6.7	1325	0740	0737	7	0	0
			0737	0807	30	0	0
			0807	0837	30	0	0
			0837	0907	30	0	0
6S5	2.7	1310	0654	0724	30	0	0
			0724	0754	30	0	0
			0754	0824	30	0	0
			0824	0854	30	0	0
			0854	0924	30	0	0
6S7	8.4	1250	0640	0745	65	0	0
			0745	0945	120	< 263	< 307
6S8	8.6	1250	0745	0815	30	0	0
			0815	0845	30	0	0
			0845	0915	30	0	0
			0915	0945	30	Malf.	-
6S9	8.6	1280	0650	0731	41	0	0
			0731	0930	119	0	0
6S10	9.9	915	0720	0950	150	0	0
6T3	4.3	915	0530	0759	149	0	0
			0759	0910	71	0	0
			0910	1110	120	0	0
6T4	4.3	830	0530	0722	112	0	0
			0722	0809	47	0	0
			0809	0915	66	Malf.	-
			0915	1115	120	0	0
6T5	3.5	825	0530	0708	98	0	0
			0708	0828	80	0	0
			0828	0924	56	0	0
			0925	1125	120	0	0



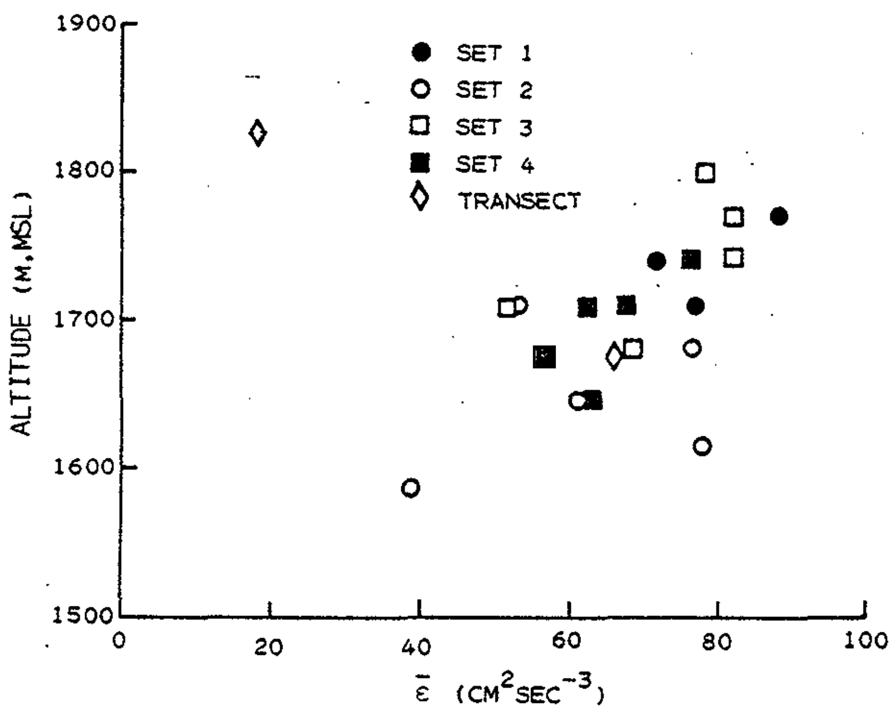


Figure 4.6-18 Turbulence measurements vs. altitude, Test 6.

indication of surface impact. Normalized concentrations at various distances indicate centerline dilution proceeded at a rate nominal for E-F stability, while turbulence dissipation rates were typical of those observed with neutral (D) dispersion conditions.

It is concluded that the meteorological conditions were conducive to elevated dispersion and that negligible surface impact is indicated by all available data.

4.7 Test Number Seven, August 1, 1976

Test 7 was conducted from the upper plant site during the early morning of August 1, 1976. A stack height of 183 m was assumed with 215 m plume rise. Release altitude was 1770 m MSL. The meteorological conditions allowed study of stable plume behavior during light southeasterly flow.

4.7.1 Synoptic Setting for Test 7. At the surface, a large high pressure system was centered over Saskatchewan and a weak low pressure system was located over eastern Washington. A 500-mb low pressure system was located several hundred kilometers west of Vancouver, while ridging was occurring over extreme southeastern British Columbia. These features produced a low-level southeasterly gradient flow that veered with height to become southerly at 500 mb. Early morning cloudiness consisted of scattered cirrus. However, cloudiness increased during the day and rain began by mid-afternoon. The deteriorating weather was caused by a short-wave trough moving into British Columbia from the south.

Surface and 500-mb maps are shown in Figure 4.7-1.

4.7.2 Meteorological Parameters for Test 7. The meteorological measurements taken during this test include temperature soundings, wind aloft, and surface winds. Temperature soundings

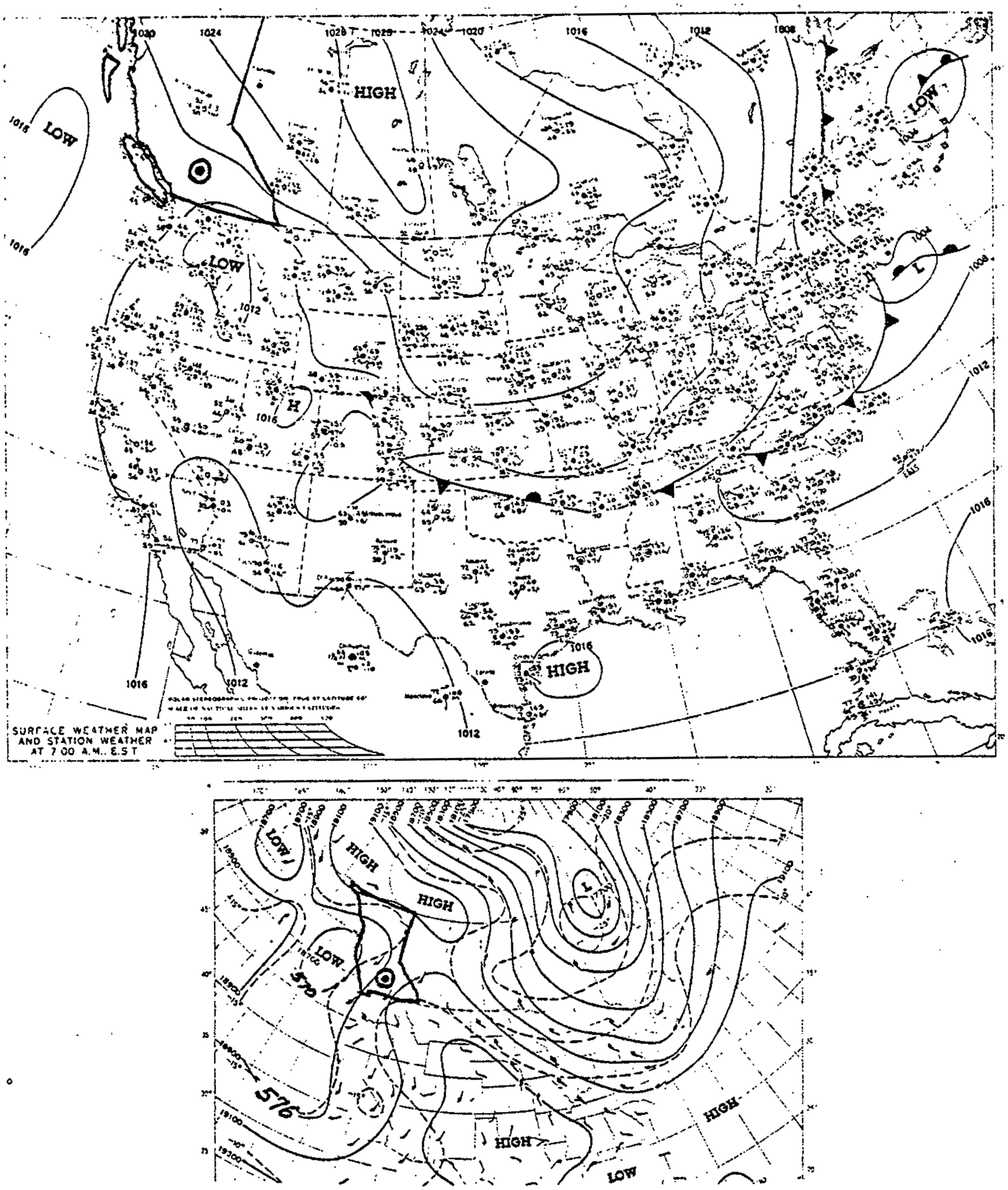


Figure 4.7-1 Surface and 500 mb maps for Test 7, August 1, 1976, 0400 PST.

were taken by minisonde, tethered sonde, and the NAWC tracer aircraft. Winds aloft data were gathered by double tracker pibal ascents and by tethered sonde. Surface wind measurements were made by the B. C. Hydro meteorological station network.

The temperature soundings taken during Test 7 are presented in Figure 4.7-2. The early morning soundings from the release site show a moderate surface inversion, about 400 m thick, extending to plume altitude. Soundings taken during the test show that the inversion was slowly eroded by surface heating. Other soundings taken around the test area reveal various structures, but generally show stable to slightly stable conditions below plume altitude and near neutral conditions above.

The surface wind data for this test may be found in Volume II, Field Data. The surface wind data show a modified diurnal regime at most low-lying sites with the switch from down-valley to up-valley flow occurring between 0800 and 1000 PST. Wind speeds were light, averaging less than 2.5 m/s. The elevated sites showed southerly flow at speeds up to 4 m/s.

Winds aloft data are presented in the wind direction and wind speed time sections, Figures 4.7-3 and 4.7-4. It can be seen that the wind field below about 1650 m largely reflects the influences of the valley circulation. The plume was apparently released near the lower boundary of the gradient flow (insomuch as direction is concerned), where winds were from the east to southeast at 2-3 m/s. Plume altitude winds remained in the east to southeast at 2-4 m/s for the duration of the test.

4.7.3 Tracer Dissemination, Test 7. Tracer release parameters for Test 7 are given in Table 4.7-1, below.

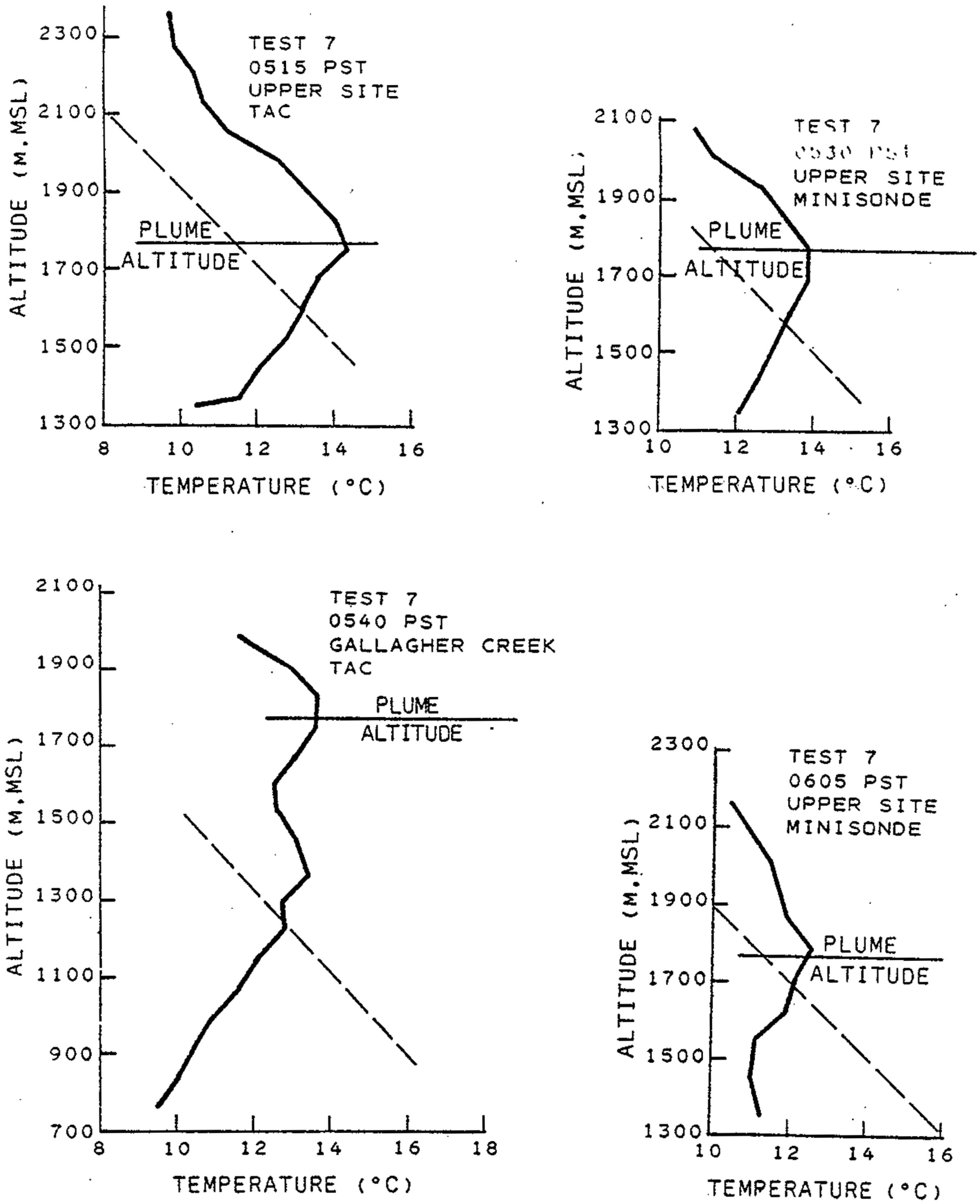


Figure 4.7-2 Vertical temperature profiles measured during Test 7.

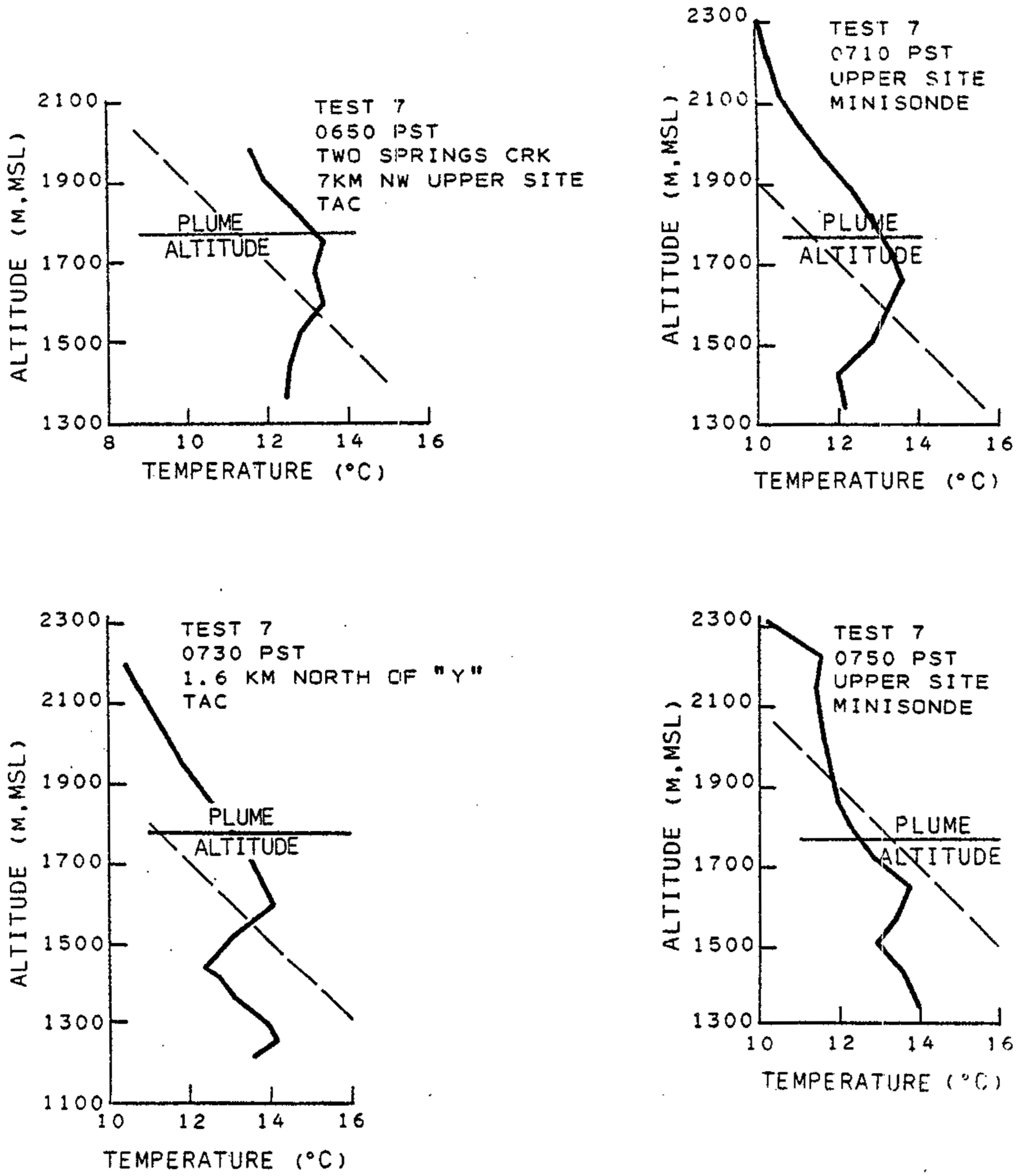


Figure 4.7-2 (Cont'd).

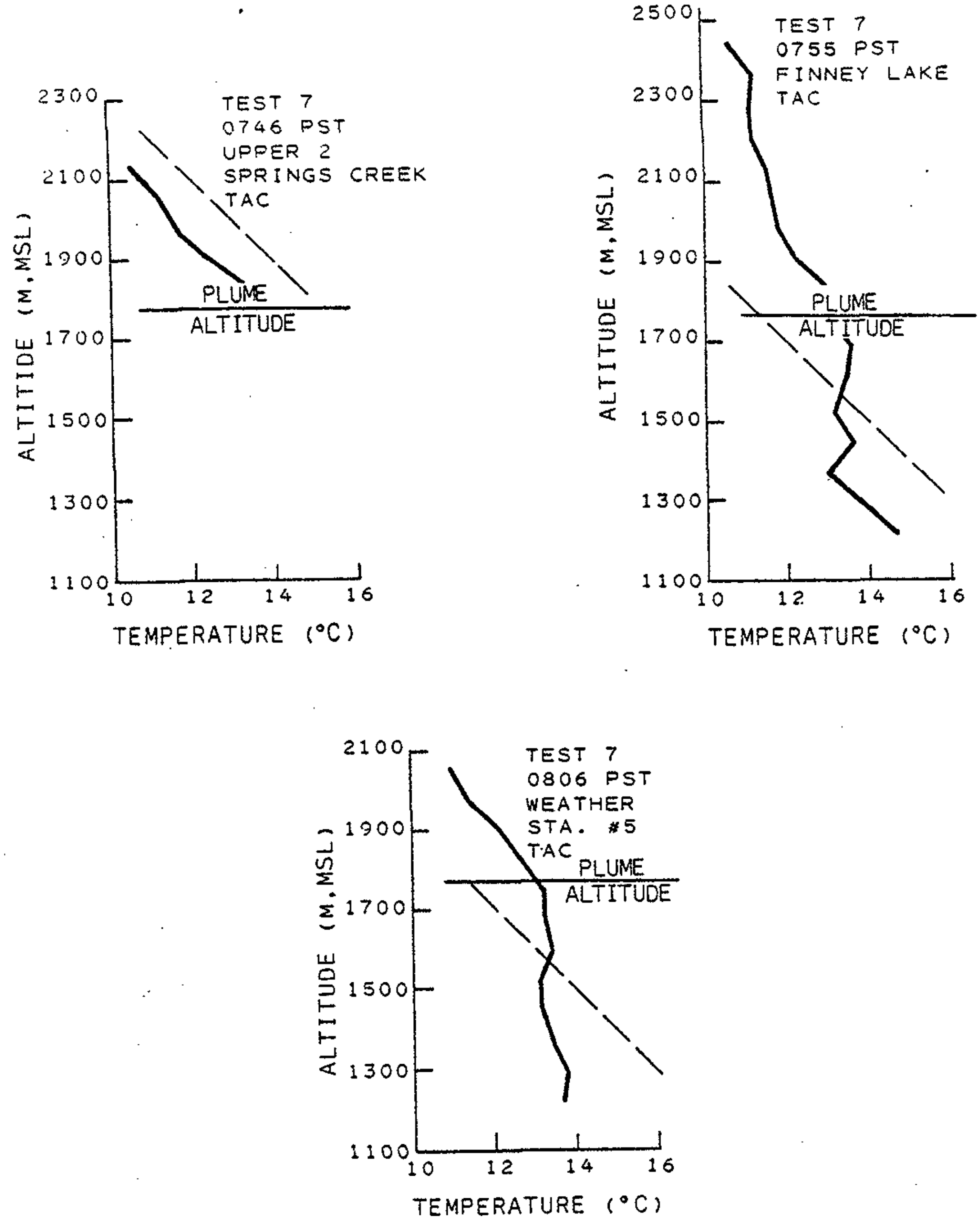


Figure 4.7-2 (Cont'd).

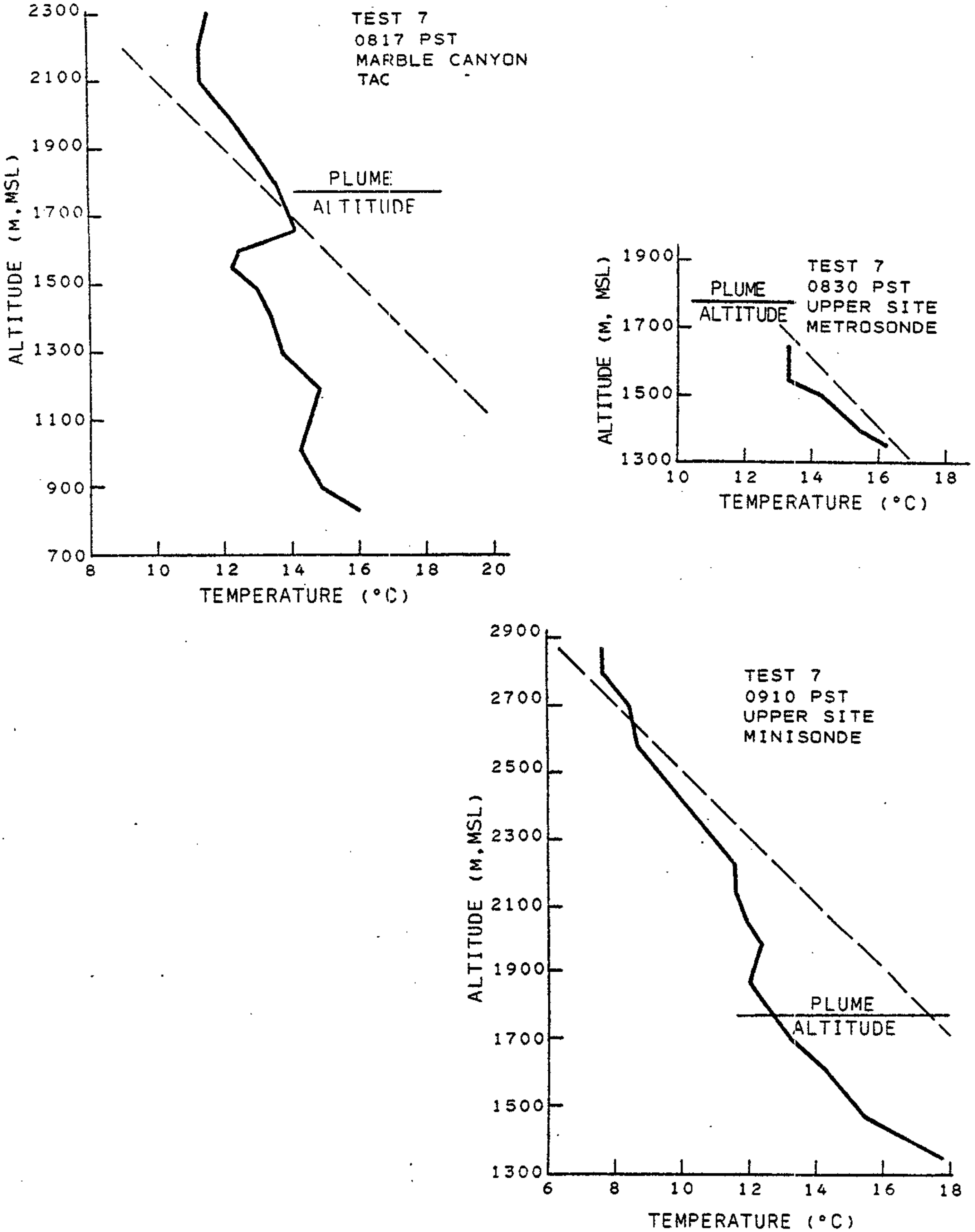


Figure 4.7-2 (Cont'd).

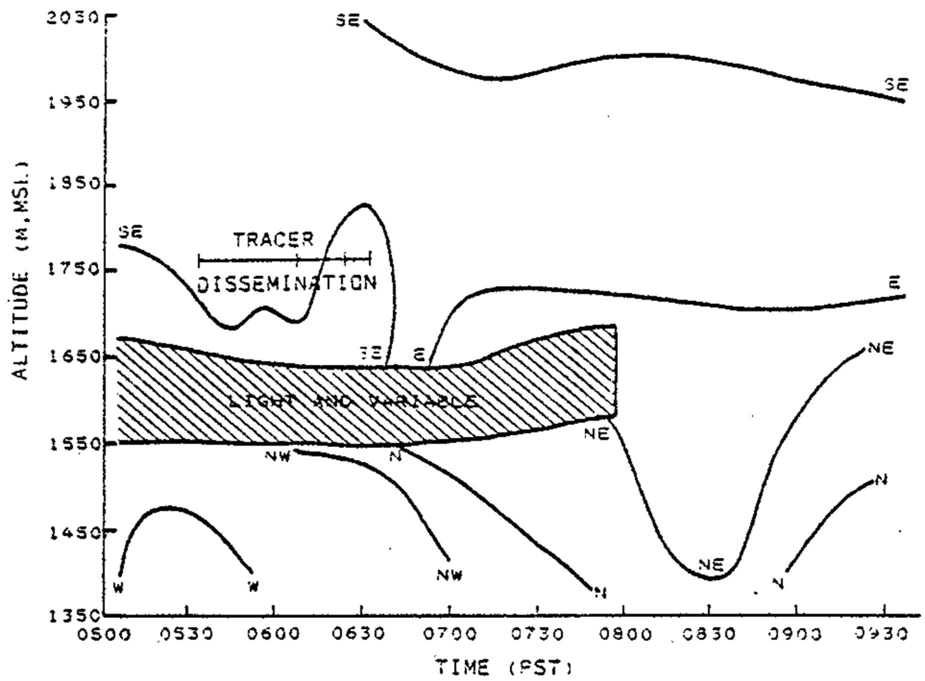


Figure 4.7-3 A time vs. altitude display of wind directions aloft measured during Test 7.

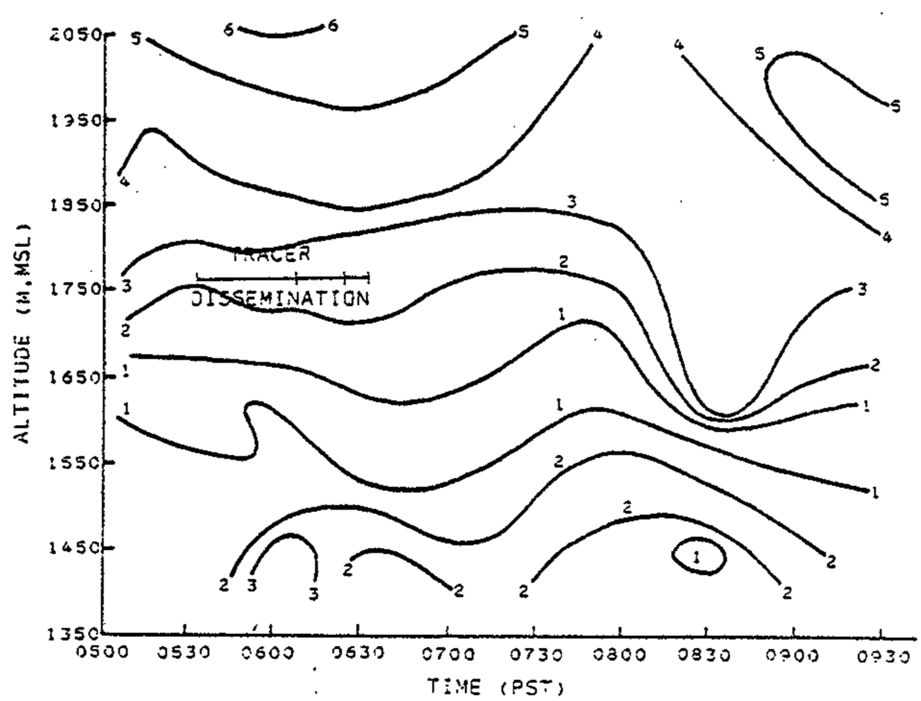


Figure 4.7-4 A time vs. altitude display of wind speeds aloft measured during Test 7. Speeds are given in m/s.

Table 4.7-1 Duration and source strength of tracer release number 7.

Location: Upper Site
Altitude: 1770 m MSL
Simulated Stack Height: 183 m
Stability Classification: E

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0531	0631	17,820	4.95
Oil Fog (1)	0531	0606	109,800	52.3
Oil Fog (2)	0624	0631	N/A	N/A

4.7.4 Visual and Photographic Observations. Initial oil-fog plume transport was toward the north-northwest at about 3 m/s. As the plume passed over the Lower Hat Creek Valley, it rose and then returned to the release altitude north of the valley, indicating the presence of cooler air over the valley. Figure 4.7-5 shows this effect at 0622 PST and also suggests that the plume was less stable while over the valley. Transport to the northwest continued until about 0700 PST. By that time, the plume was near the elevation of the terrain of the Marble Range and the northwestward transport ceased. During the next 90 minutes, the entire plume drifted to the west and southwest at about 1 m/s. At 0738 PST, Figure 4.7-6 shows the plume nearing the rugged eastern side of Marble Canyon. By 0803 PST, the plume was over Marble Canyon as far north as Crown Lake and apparently below the maximum elevation of the eastern side of Marble Canyon (Figure 4.7-7). Observation ended at about 0830 PST when the faint plume was over the elevated terrain on the west side of Marble Canyon (Figure 4.7-8).

Approximate plume outlines at selected times during the test are shown in Figure 4.7-9.

Figure 4.7-5 Photo, Test 7. This view towards the northeast shows the tracer plume rising over the center of Hat Creek Valley, then returning to near release altitude. Source is to the right, 0622 PST.

Figure 4.7-6 Photo, Test 7. The tracer plume can be seen nearing the elevated terrain of the Marble Range. View is towards the east across Marble Canyon, 0638 PST.

Figure 4.7-7 Photo, Test 7. By 0703 PST the plume was drifting across Marble Canyon. View is toward the southeast with the release point upper center.

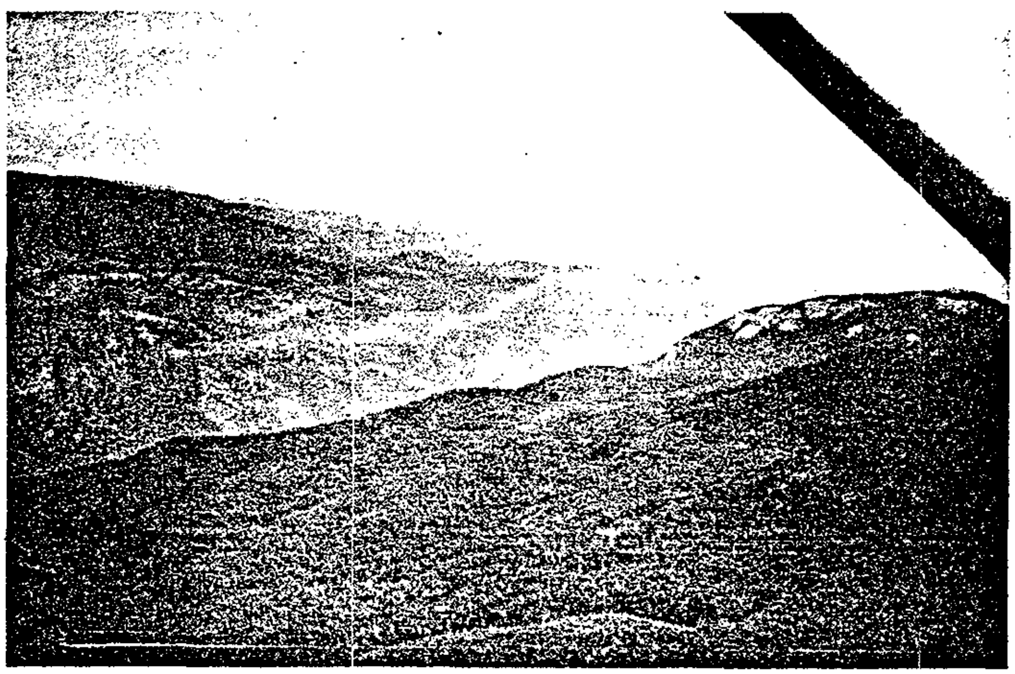


Figure 4.7-8 Photo, Test 7. By 0730 PST the last visible portions of the tracer plume dispersed west of Marble Canyon. View is towards the east, the plant site in the right background.

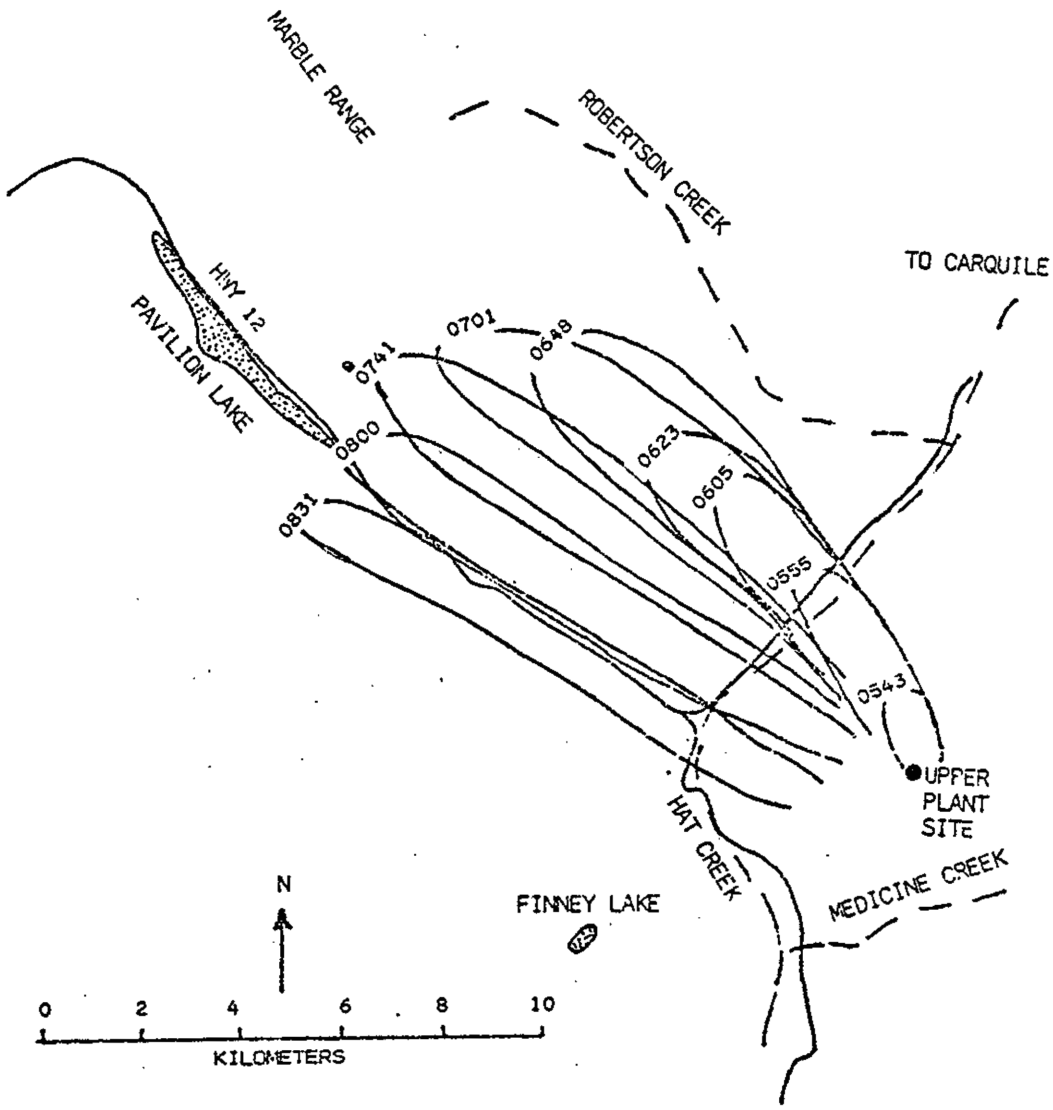


Figure 4.7-9 Plume outlines at various times during Test 7.

4.7.5 Oil-Fog Measurements. Oil-fog measurements for Test 7 consisted of two sets of crosswind patterns flown 3.3 and 7.3 km downwind. Other measurements were made during vertical temperature soundings.

The first set of crosswinds was made northwest of the release over the center of Lower Hat Creek Valley as shown in Figure 4.7-10 between 0600 and 0620 PST. Nine passes were made at altitudes between 1830 and 1710 m MSL. The maximum concentration, equivalent to 33,500 μgm^{-3}, was found at the release altitude, 1700 m MSL. A plot of maximum concentration vs. altitude for these passes, as well as a plot of distance vs. concentration for the 1770 m MSL pass are given in Figure 4.7-11. The plume distribution with altitude, when compared with temperatures measured during the passe., indicate that the plume was confined above the inversion which can be seen between 1700 and 1800 m MSL on the early morning soundings. Only very slight leakage into the inversion layer is indicated. The Gallagher Creek sounding made at 0540 PST shows that the top of this inversion was somewhat higher over the Hat Creek Valley than over the plant site, thus providing a mechanism for the visually observed rise in the plume as it passed over the center of the valley.

The values of σ_y, σ_z, and $\frac{\chi\bar{u}}{Q}$ for these passes have been computed and are displayed in Figures 4.7-12 and 4.7-13. The measured dispersion coefficients suggest very stable plume geometry. The value of $\frac{\chi\bar{u}}{Q}$ indicates a somewhat less stable E type dilution rate at the centerline.

The second set of crosswinds were flown over the slopes of the Marble Range, across Hat Creek from the release, between 0634 and 0641 PST. Here the centerline was found at an altitude of 1785 m MSL with a maximum equivalent concentration of 11,282 μgm^{-3}. The distance vs. concentration plot for the 1785 m pass as well as

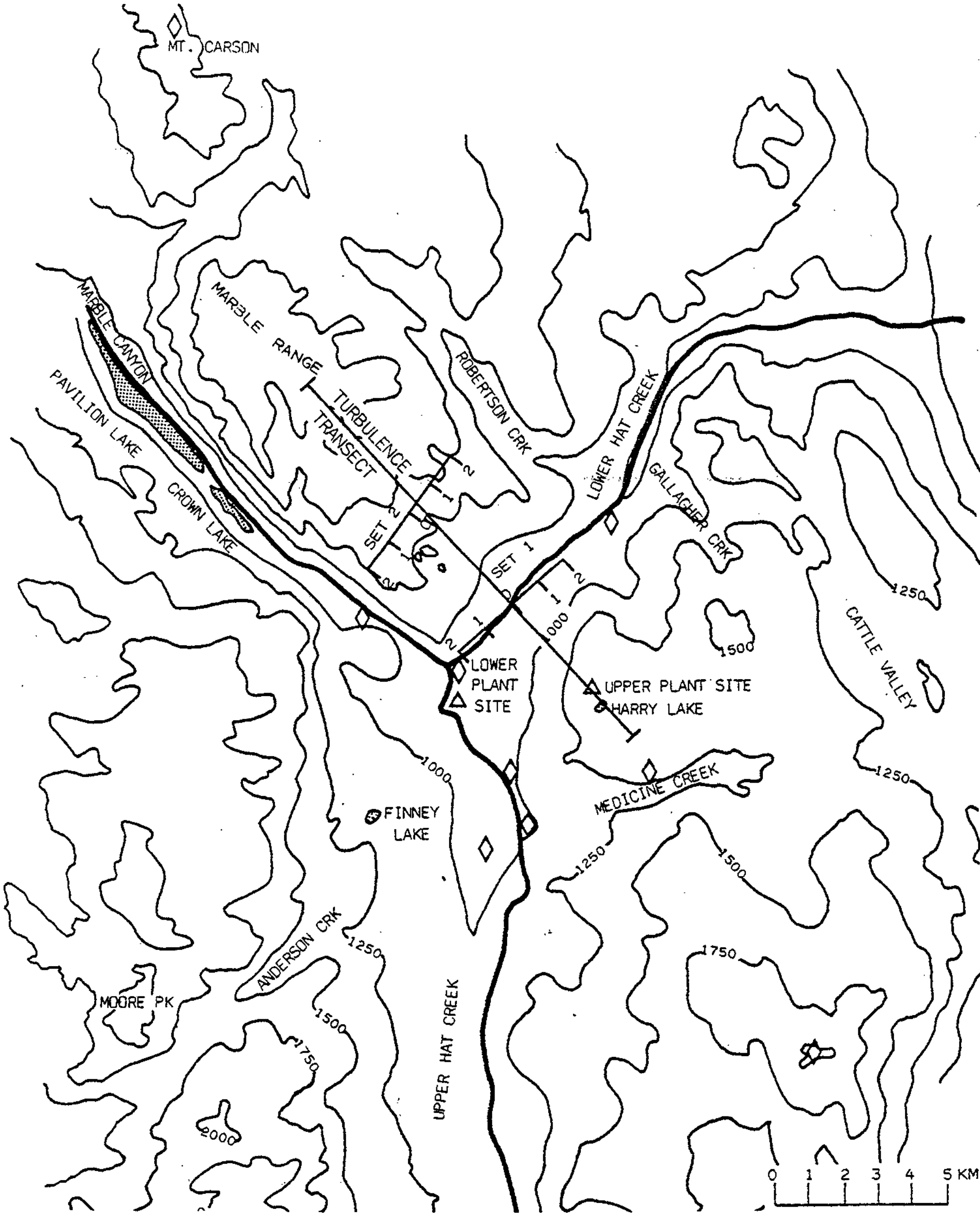


Figure 4.7-10 Location of oil-fog crosswind patterns and turbulence transects, Test 7. Distances are in kilometers.

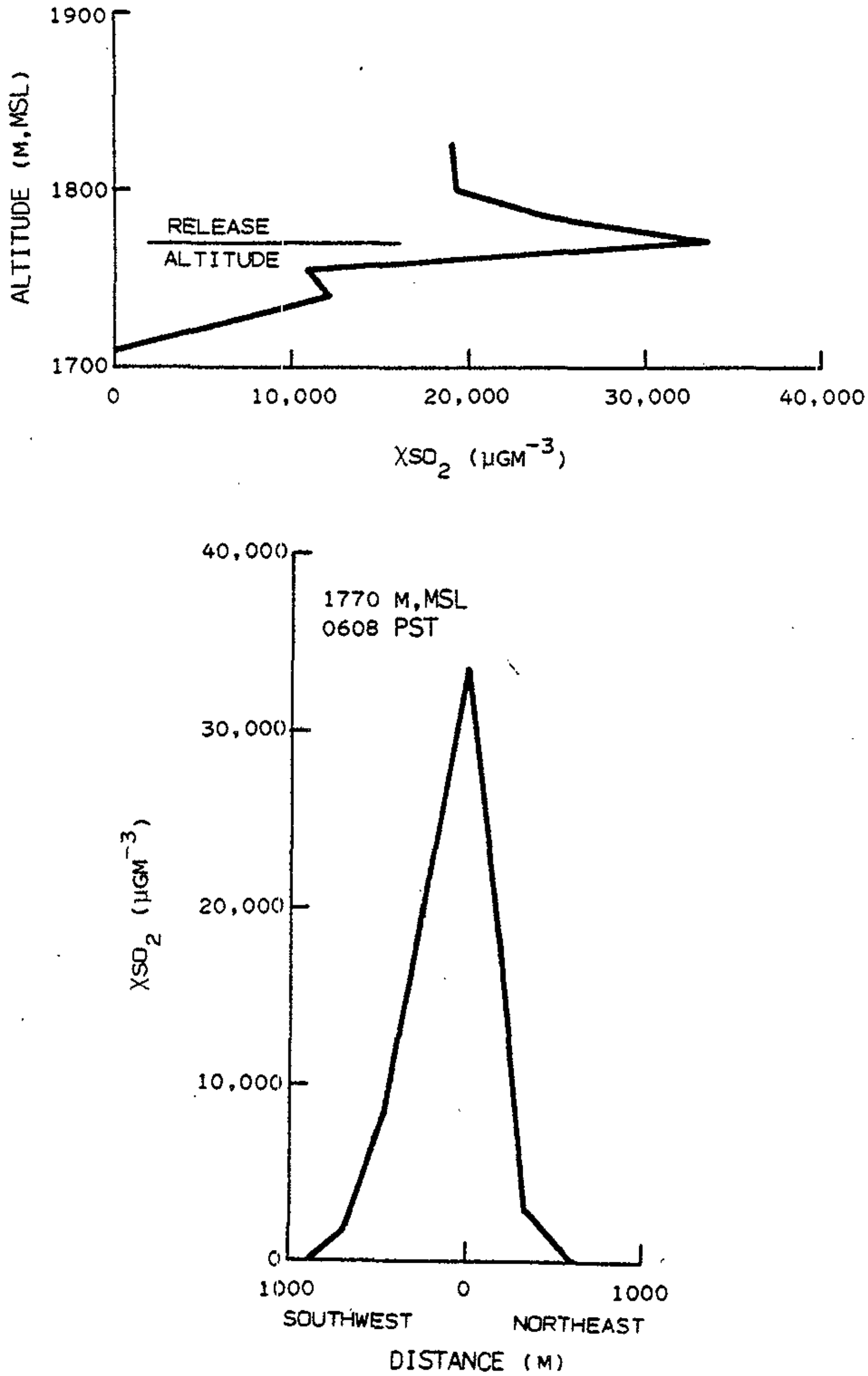


Figure 4.7-11 Horizontal and vertical plume centerline distributions, Test 7, Set 1.

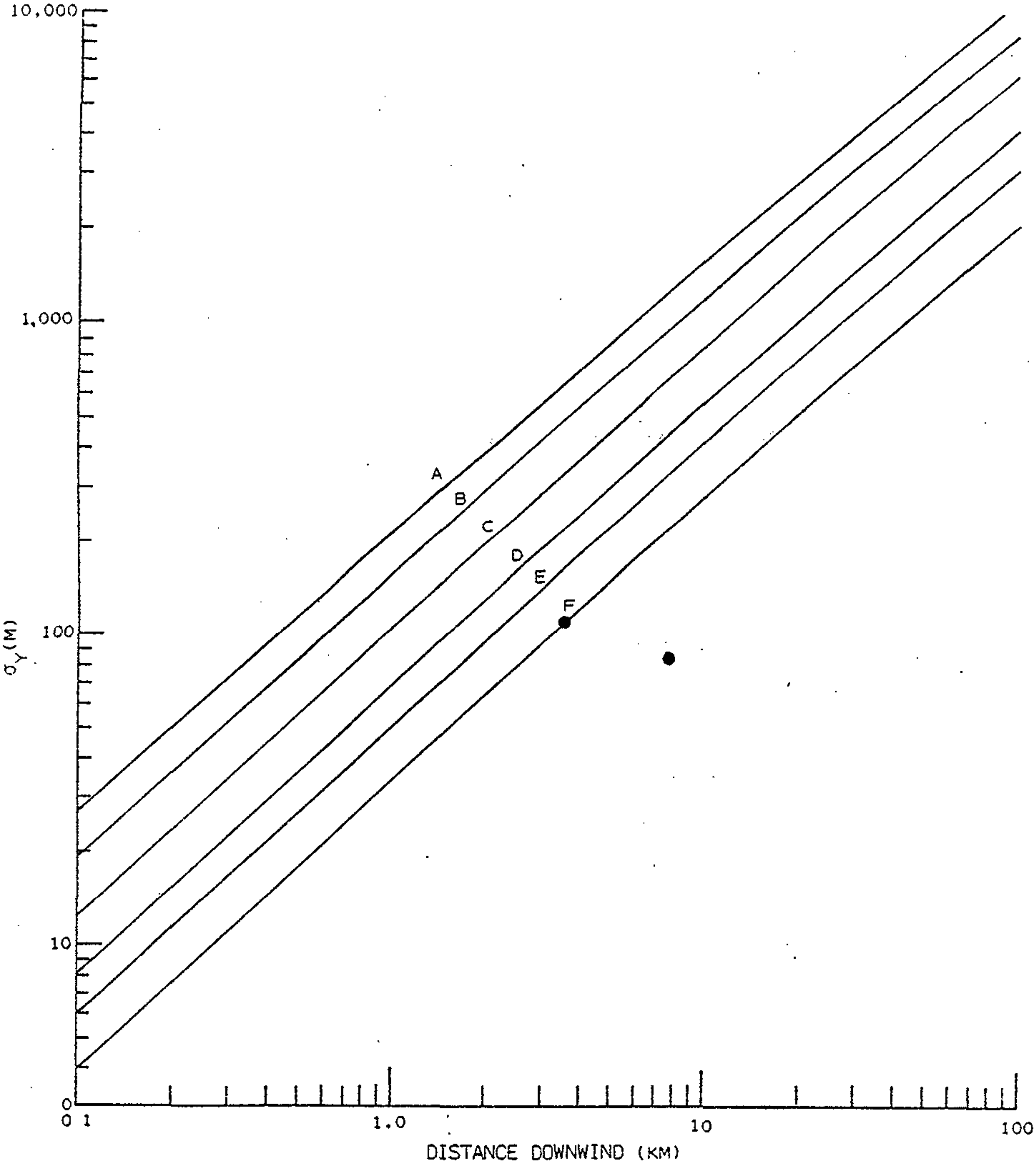


Figure 4.7-12 Measured values of σ_y and σ_z, Test 7.

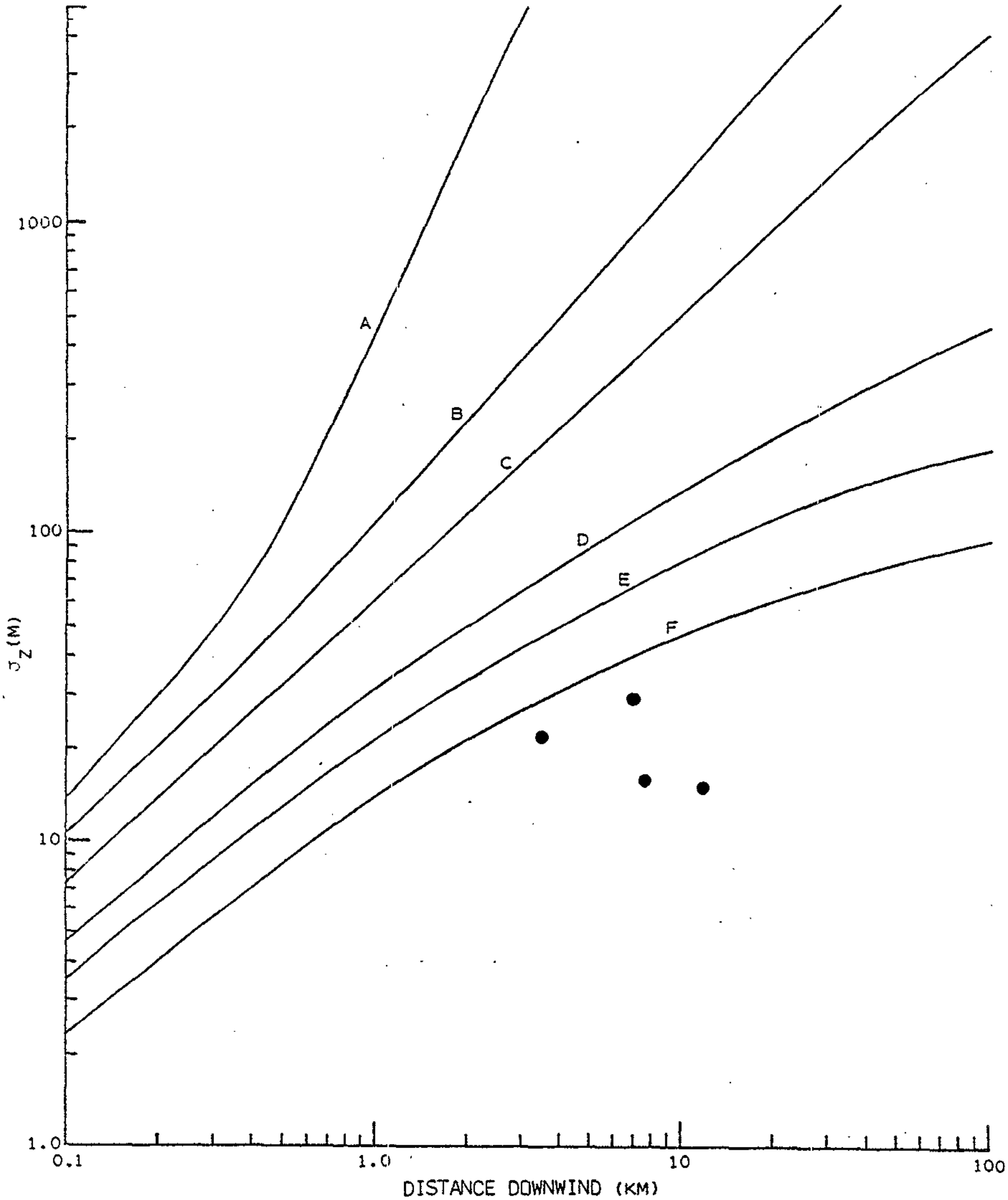


Figure 4.7-12 (Cont'd).

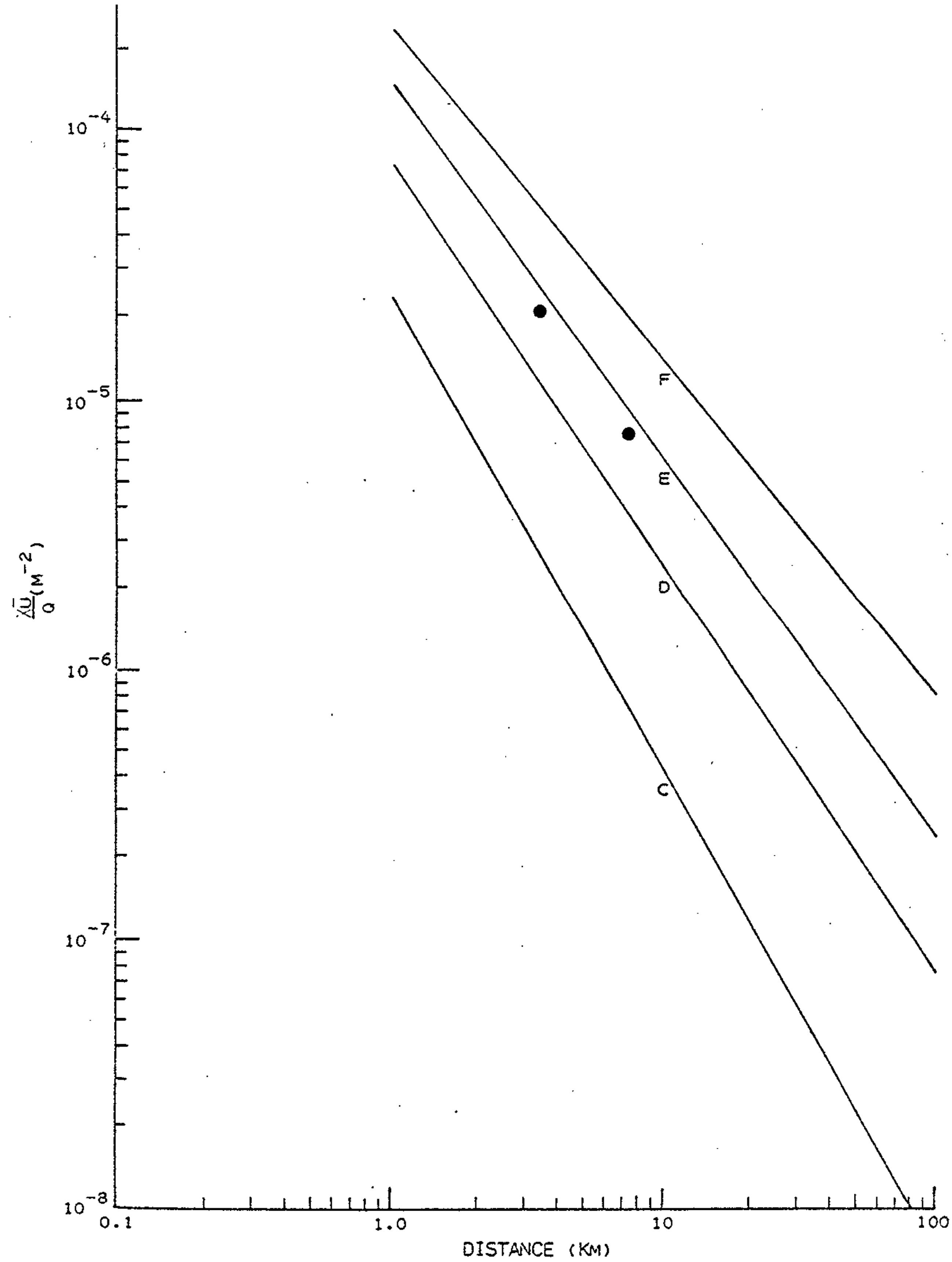


Figure 4.7-13 Normalized centerline concentrations, Test 7.

the altitude vs. maximum concentration plot for this set of measurements can be found in Figure 4.7-14. Here, as in Set 1, a comparison of plume distribution with altitude shows the centerline above the top of the inversion and only very low concentrations within the inversion layer itself. The computed values of σ_y, σ_z, and $\frac{\chi \bar{u}}{Q}$ for these passes are given in Figures 4.7-12 and 4.7-13. The values of both dispersion coefficients appear to have decreased since Set 1, while the value of $\frac{\chi \bar{u}}{Q}$ appears to agree well with the predicted E curve.

Other oil-fog measurements are available from a temperature sounding made at 0650 PST over Two Springs Creek, 7 km northwest of the release point. These data showed the plume to be centered at 1800 m. The plume extended down to about 1760 m MSL, the level of the top of the inversion. Upwards, the plume extended to about 1840 m MSL, although very low concentrations appear to have been present as high as 2135 m MSL. A measurement of σ_z at this location gives a value of 30 m.

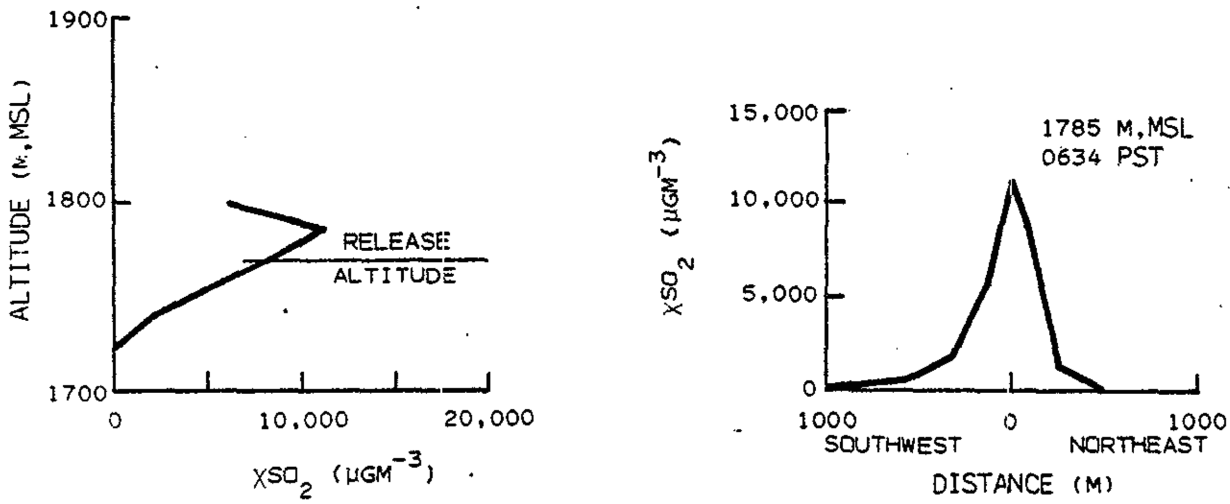


Figure 4.7-14 Horizontal and vertical plume centerline distributions, Test 7, Set 2.

A spiral through the plume over the headwaters of Two Springs Creek, 12 km northwest of the plant site showed the plume to extend from at least 2165 m MSL to near the surface. The main portion of the plume was found between 1905 m MSL and 1845 m MSL (10 m AGL) with the centerline at 1890 m. These measurements indicate concentrations of up to 1485 μgm^{-3} at an altitude of 10 m AGL.

Another temperature sounding taken about 5 km west-northwest of the release showed the plume to extend, in very low concentrations, to as high as 2135 m MSL. The main portion of the plume was found between 1965 and 1600 m MSL with the peak value at 1870 m MSL. The level of the top of the inversion was 1600 m MSL and only threshold concentrations were observed within the inversion layer or below.

A third temperature sounding, taken over the center of Marble Canyon, showed threshold concentrations to extend from 2225 m MSL to 1790 m MSL rising to a maximum at 1690 m MSL and dropping to zero at 1660 m MSL, the top of the inversion layer. The bottom of the sounding, over Crown Lake, showed a haze layer extending from the surface to 50 m AGL. The haze, mainly due to campfires, showed a maximum particulate concentration of about 30 μgm^{-3}.

4.7.6 Aerial SF_6 Measurements. Seventeen aerial grab samples were taken with the helicopter sampling system at locations shown in Figure 4.7-15. Table 4.7-2 provides sampling information. It can be seen that of the thirteen samples taken over elevated terrain, northeast of Marble Canyon, six contained measurable SF_6. Those six were all taken at altitudes of more than 1735 m MSL, near the top of or above inversion height, and were from a small area near surface sampler site 7S9. The maximum measured concentration, from samples 7H8, was equivalent to 2508 μgm^{-3}. Samples 7H7 and 7H10 showed concentrations of 1384 and 2204 μgm^{-3}, respectively, within 30 m of the ground. Four samples were taken

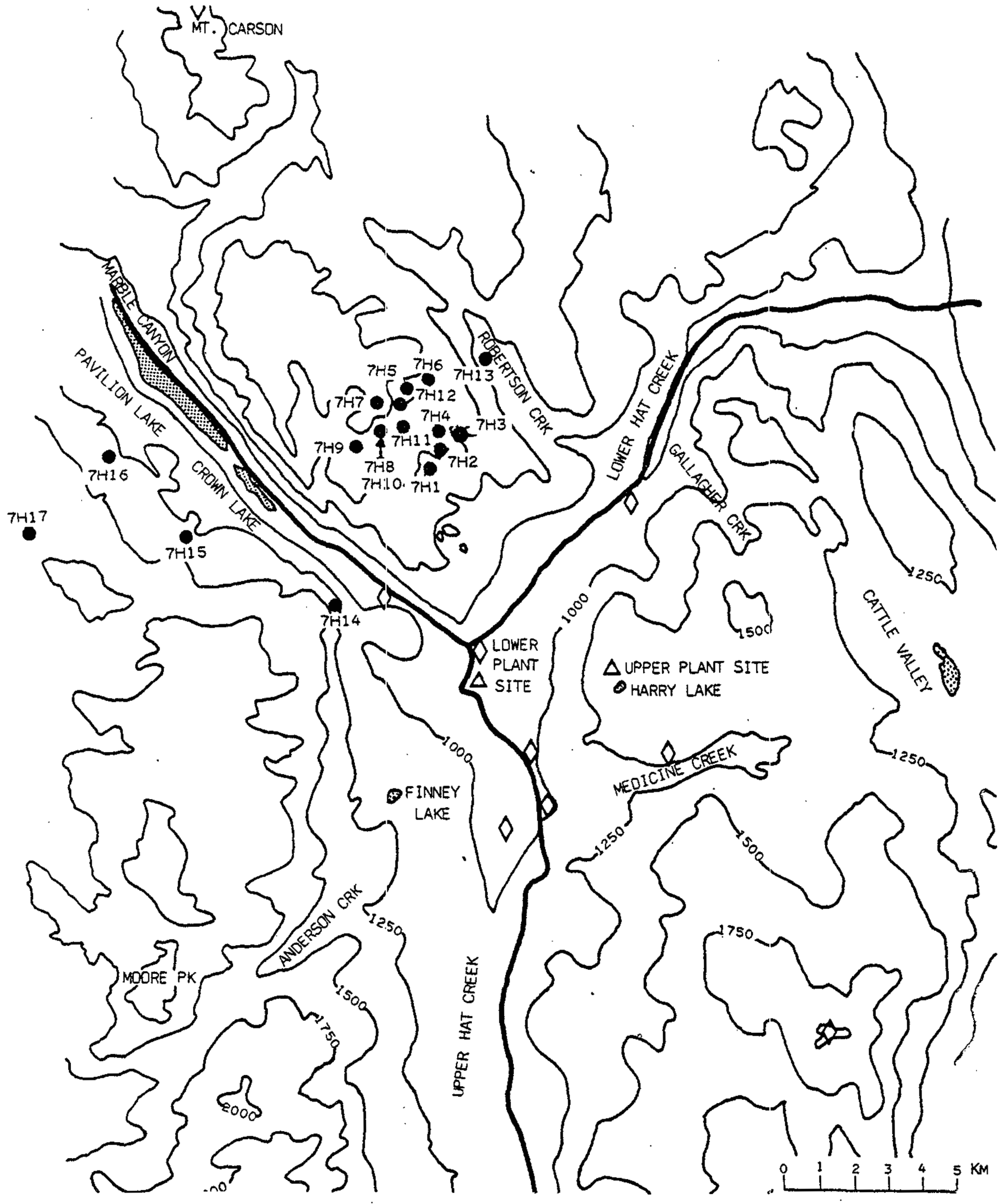


Figure 4.7-15 Location of aerial SF_6 measurements, Test 7.

Table 4.7-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m)		Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3})	
		MSL	AGL			Ambient	NTP
7H1	8.5	1645	20	0645	1	0	0
7H2	8.5	1645	60	0649	1	0	0
7H3	8.6	1645	20	0655	1	0	0
7H4	8.7	1675	90	0659	1	0	0
7H5	10.4	1735	25	0700	1	0	0
7H6	10.0	1735	75	0702	1	0	0
7H7	11.0	1830	30	0704	1	1384	1655
7H8	10.4	1830	90	0708	1	2508	3000
7H9	10.3	1735	55	0715	1	112	133
7H10	10.4	1770	30	0717	1	2204	2635
7H11	9.6	1770	125	0718	1	2464	2964
7H12	10.3	1770	110	0720	1	308	368
7H13	10.0	1585	335	0722	1	0	0
7H14	8.7	1585	135	0813	1	0	0
7H15	11.5	1585	365	0816	1	0	0
7H16	15.5	1585	350	0820	1	0	0
7H17	15.5	1465	155	0824	1	0	0

over the slopes southwest of Marble Canyon; none of these contained measurable concentrations of SF_6.

4.7.7 Surface SF_6 Measurements. Nineteen ground SF_6 sampler sites were employed, as shown in Figure 4.7-16. Table 4.7-3 gives supplementary data. Of these, significant amounts of SF_6 were detected at only two sites, 7S8 and 7S9. Equivalent SO_2 concentrations were between 182 and 776 μgm^{-3} in the 73 to 82 minute samples. These two ground samplers were at heights of about 35 and 50 m above the top of the inversion (1750 m MSL) as indicated by the 0650 PST sounding over Upper Two Springs Creek. Sampler 2S10, nearby but 125 m below the inversion, received no measurable SF_6. No SF_6 was detected at sites along the Marble Canyon Road or the Hat Creek Road. Near background levels of SF_6 were detected at two sites near the plant site.

4.7.8 Turbulence Measurements. Turbulence measurements for Test 7 are available from the two sets of oil-fog crosswinds and two longer distance transects (see map, Figure 4.7-10). The results of these measurements are plotted against altitude in Figure 4.7-17.

It can be seen that the turbulence environment at all altitudes during crosswind Set 1 over the center of the valley was very light. Intermittence values were more scattered though no trend with altitude was apparent. The turbulence values from Set 2 are much higher and show a trend to increase with altitude. The general increase in turbulence from Set 1 to Set 2 apparently resulted from increasing mechanical turbulence and surface heating over the slopes, while the trend to increase with altitude reflects the presence of the shear layer and associated inversion top which marked the top of the valley circulation at about 1600 m MSL. Intermittence values from Set 2 were scattered in a similar fashion to those from Set 1.

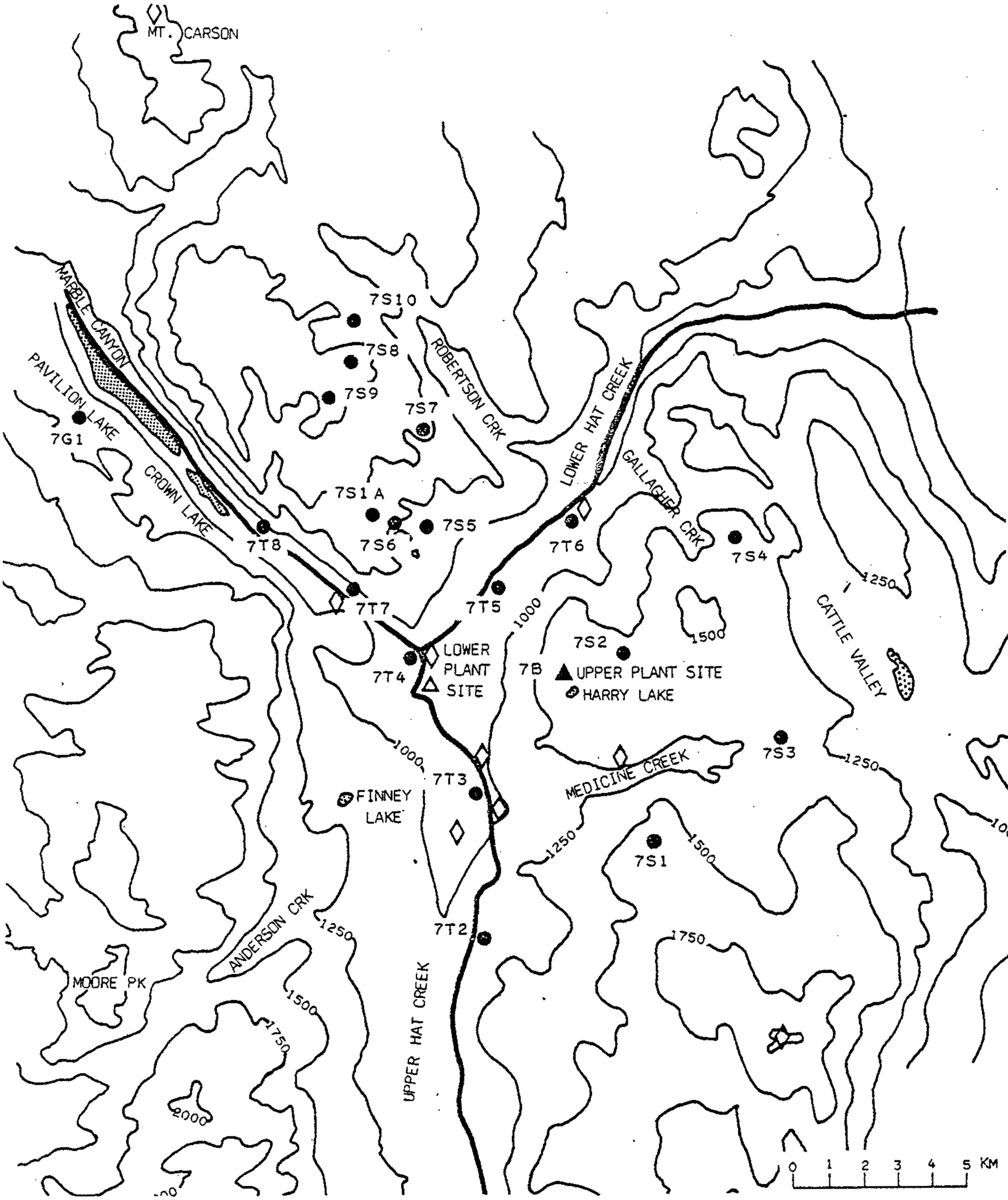


Figure 4.7-16 Location of surface SF_6 samplers, Test 7.

Table 4.7-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
7S1	5.2	1540	0520	0550	30	0	0
			0550	0620	30	0	0
7S1A	7.0	1295	0700	0730	30	Malf.	-
			0730	0800	30	<22	<26
			0800	0830	30	0	0
			0830	0900	30	0	0
			0900	0930	30	0	0
			0930	1000	30	Malf.	-
7S2	1.6	1435	0515	0545	30	0	0
			0545	0615	30	0	0
			0615	0645	30	0	0
			0645	0715	30	0	0
			0715	0745	30	Malf.	-
			0745	0815	30	<22	<26
7S3	6.3	1450	0510	0540	30	Malf.	-
			0540	0610	30	0	0
			0610	0640	30	0	0
			0640	0710	30	0	0
			0710	0740	30	0	0
			0740	0810	30	0	0
7S4	6.6	1325	0505	0535	30	0	0
			0535	0605	30	0	0
			0605	0635	30	Malf.	-
			0635	0705	30	0	0
			0705	0735	30	0	0
			0735	0805	30	0	0
7S5	5.9	1160	0620	0650	30	0	0
			0650	0720	30	0	0
			0720	0750	30	0	0
			0750	0820	30	0	0
			0820	0850	30	0	0
			0850	0920	30	0	0
7S6	6.9	1220	0625	0715	50	Malf.	-
			0715	0855	100	Malf.	-
			0855	1000	65	0	0

Table 4.7-3 (cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3}) Ambient	NTP
7S7	8.3	1525	0635	0705	30	0	0
			0705	0735	30	0	0
			0735	0805	30	0	0
			0805	0835	30	0	0
			0835	0905	30	0	0
			0905	0935	30	0	0
7S8	11.3	1785	0650	0725	35	<22	<26
			0725	0847	82	182	218
			0847	0953	66	0	0
7S9	10.8	1800	0655	0730	35	Malf.	-
			0730	0843	73	276	330
			0843	0950	67	0	0
7S10	11.8	1645	0727	0850	83	0	0
			0850	0957	67	0	0
7G1	16.1	1250	0817	0827	10	0	0
7T2	6.5	975	0530	0652	82	0	0
7T3	4.3	930	0530	0705	95	0	0
7T4	4.7	855	0530	0715	105	0	0
			0715	0800	45	0	0
			0800	0930	90	0	0
7T5	3.6	840	0530	0625	55	0	0
			0625	0815	50	0	0
7T6	4.8	795	0630	0617	47	0	0
			0617	0820	63	0	0
7T7	7.4	825	0725	0900	95	0	0
7T8	9.6	795	0735	0900	85	0	0
7B	0.0	1350	0445	0530	45	0	0
			0530	0600	30	0	0
			0600	0630	30	0	0
			0630	0700	30	0	0
			0700	0730	30	0	0
			0730	0800	30	0	0
			0800	0830	30	0	0
			0830	0845	15	<22	<26

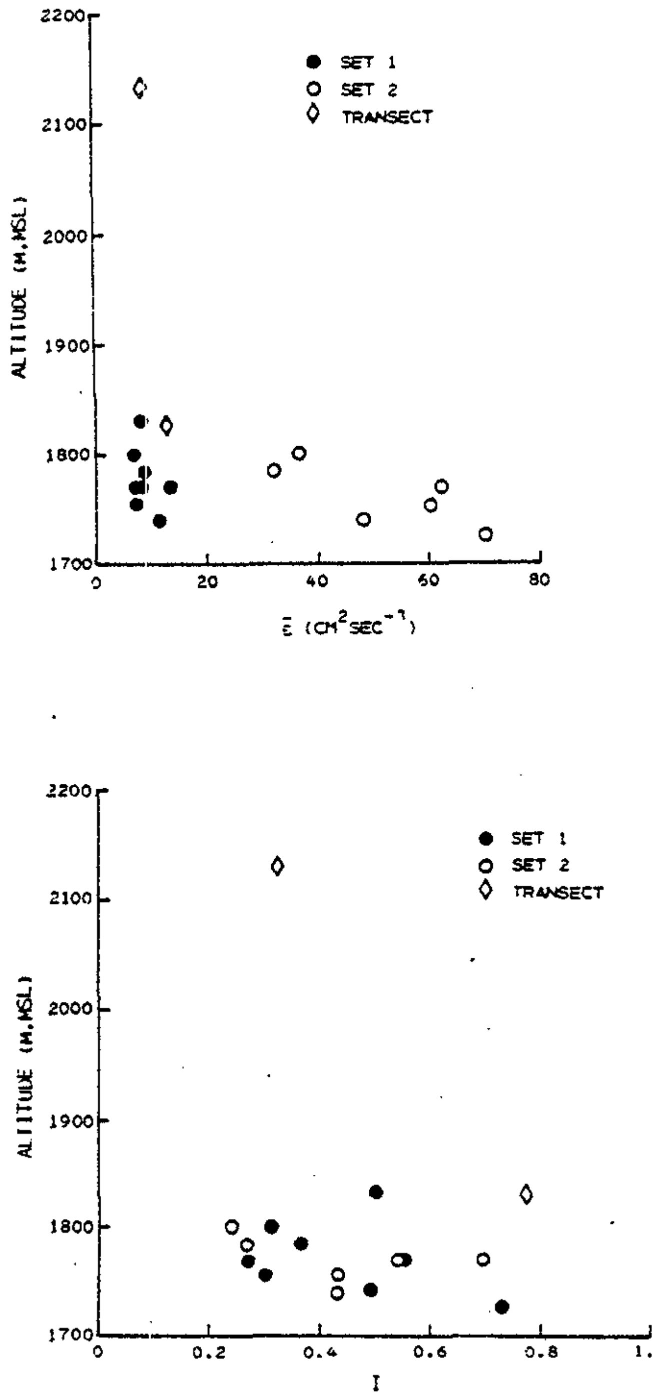


Figure 4.7-17 Turbulence measurements vs. altitude, Test 7.

The turbulence transects were flown at altitudes of 1825 and 2130 m MSL from the release to over the Marble Range, between 0710 and 0720 PST. These showed low turbulence values indicative of stable dispersion at both altitudes and moderate intermittence at 2130 m MSL and a rather high value at 1825 m MSL.

4.7.9 Summary of Test 7. The Test 7 tracer plume was released from the upper plant site at an altitude of 1770 m MSL. A stack height of 183 m was assumed. Dissemination was made at the top of a thick inversion layer with east to southeast flow at speeds of 2 to 3 m/s. The plume traveled first to the northwest over the Marble Plateau, then moved westward across Marble Canyon and the elevated terrain beyond. Ground impact occurred over the Marble Plateau where sluggish fumigation produced low, but measurable, one-hour surface concentrations of at least 276 μgm^{-3}. Apparently only those samplers above the top of the inversion layer received measurable concentrations of SF_6. Aerial measurements of both SF_6 and oil-fog also indicate that the bulk of the tracer plume was confined above the inversion. The aerial SF_6 measurements show concentrations at 30 m AGL were about eight times long-term surface concentrations at the same location. Maximum plume centerline concentrations over the high ground, as measured from the oil-fog plume were another five times higher. The normalized concentrations indicate this plume experienced a rate of centerline dilution comparable with the published values for E type stability. Turbulence dissipation rates were characteristic of very stable conditions over the valley, while over the slopes neutral conditions were indicated.

In summary, surface impact occurred only at sites above the release altitude where one-hour concentrations of at least 276 μgm^{-3} were found. More extensive fumigation was prevented by the inversion layer below and the fact that insolation was rather weak. By the time fumigation occurred (about 0830 to 0900 PST), the plume was diffuse to the point that surface concentrations were undetectable.

4.8 Test Number Eight, August 5, 1976

The Test 8 tracer release was conducted from the upper plant site on the morning of August 5, 1976. A stack height of 185 m and plume rise of 275 m were assumed, giving a release altitude of 1830 m MSL. The meteorological conditions dictated study of neutral plume behavior over the rough terrain east and south of the proposed plant site.

4.8.1 Synoptic Setting for Test 8. At the surface, the project area was between two high pressure systems, one centered over central Saskatchewan and the other a similar distance to the west. Due to the blocking effect of the Rocky Mountains, the western high pressure system exerted the greatest effect over the project area and, as a result, the low-level gradient flow was northwesterly to northerly. A 500-mb low pressure system, located off the California-Oregon border, resulted in a high level, southeasterly to easterly flow. Morning cloudiness over the project area consisted of broken altocumulus and cirrus with some scud over the hills.

Surface and 700-mb maps are shown in Figure 4.8-1.

4.8.2 Meteorological Paremeters for Test 8. Measurements made during the field operations included double tracked pilot balloon and minisonde ascents from the proposed Harry Lake site for wind and lapse rate data, plus surface wind measurements from the B. C. Hydro station network. The NAWC tracer aircraft provided temperature soundings from various locations around the test area.

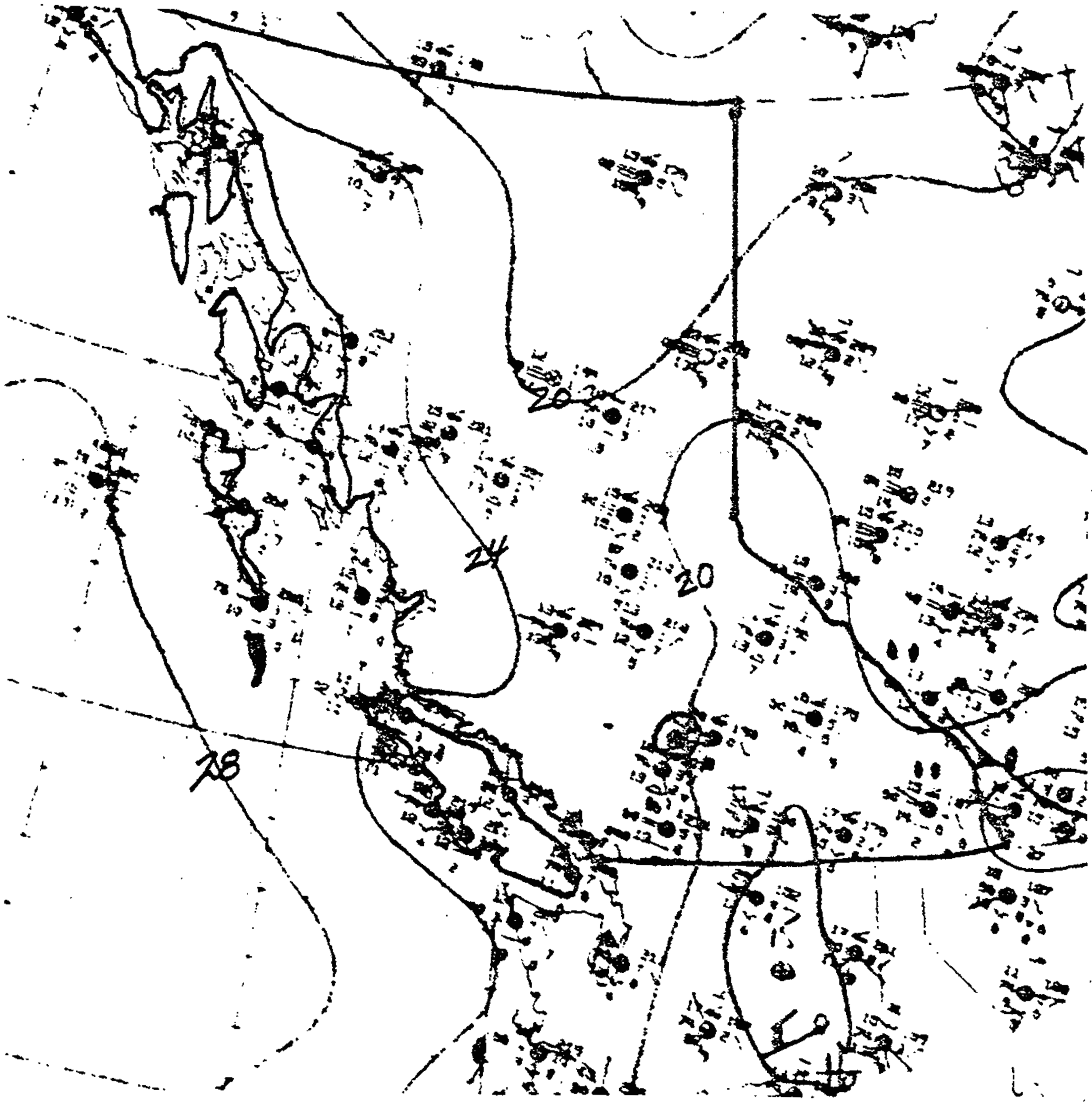


Figure 4.8-1 Surface and 500 mb charts for Test 8, August 5, 1976.

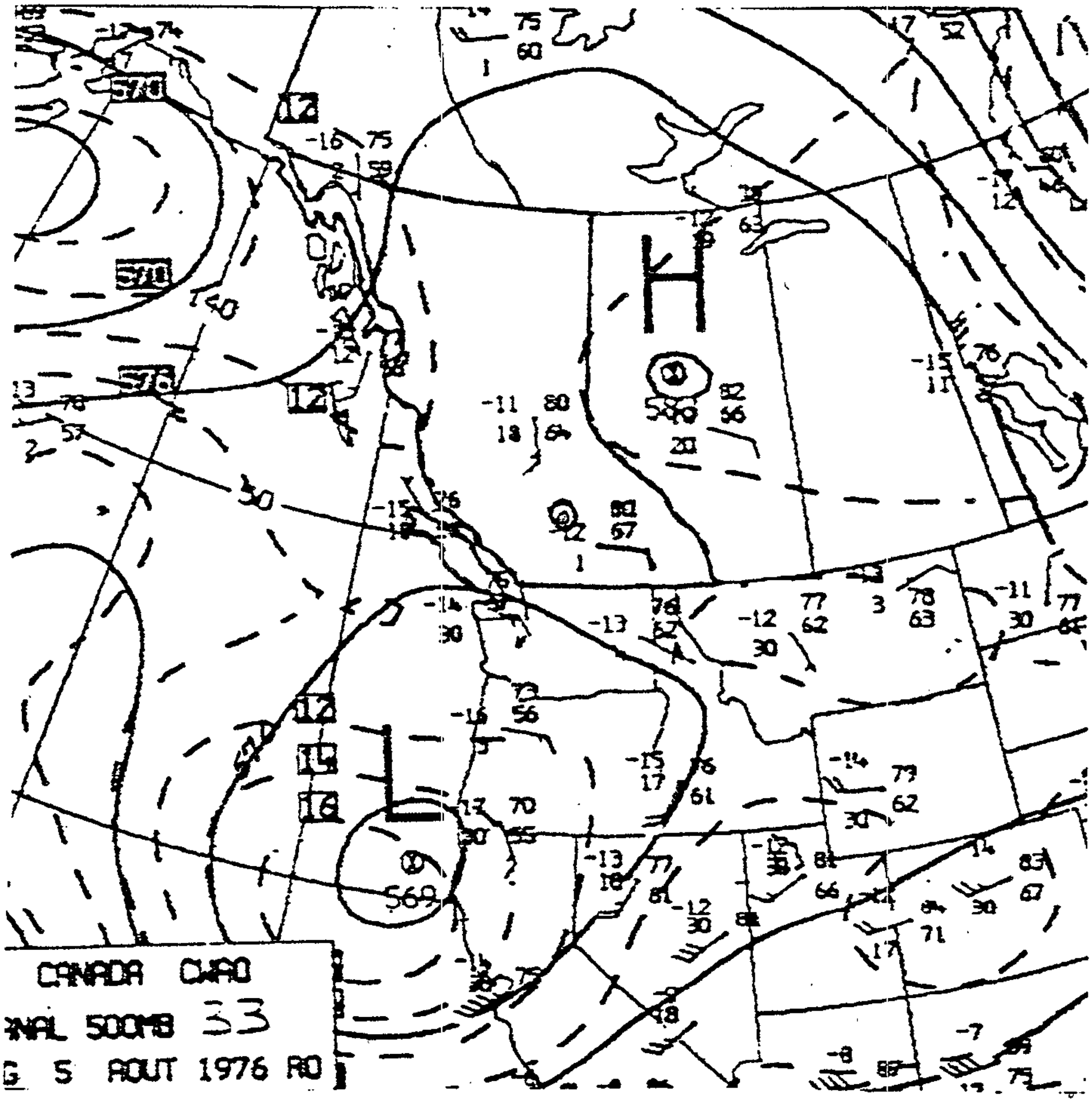


Figure 4.8-1 (Cont'd.)

The plots of the temperature soundings taken during this test are shown in Figure 4.8-2. It can be seen that near-neutral conditions prevailed at release altitude throughout the test. Soundings made in the Hat Creek Valley and Cattle Valley indicated a weakly-developed surface based inversion extending up to 1300 to 1400 m MSL. Wind and cloud cover apparently prevented inversion formation at higher locations such as the plant site.

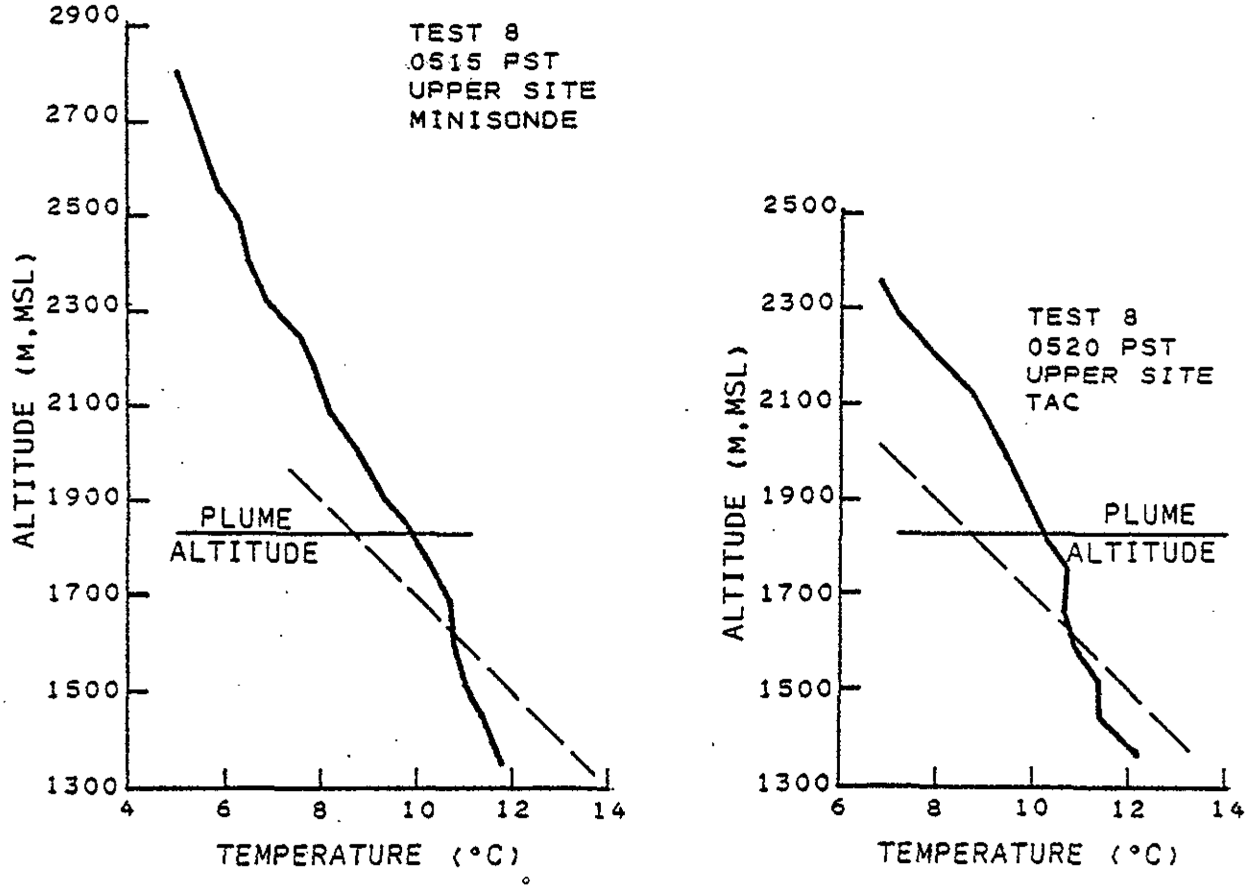


Figure 4.8-2 Vertical temperature profiles measured during Test 8.

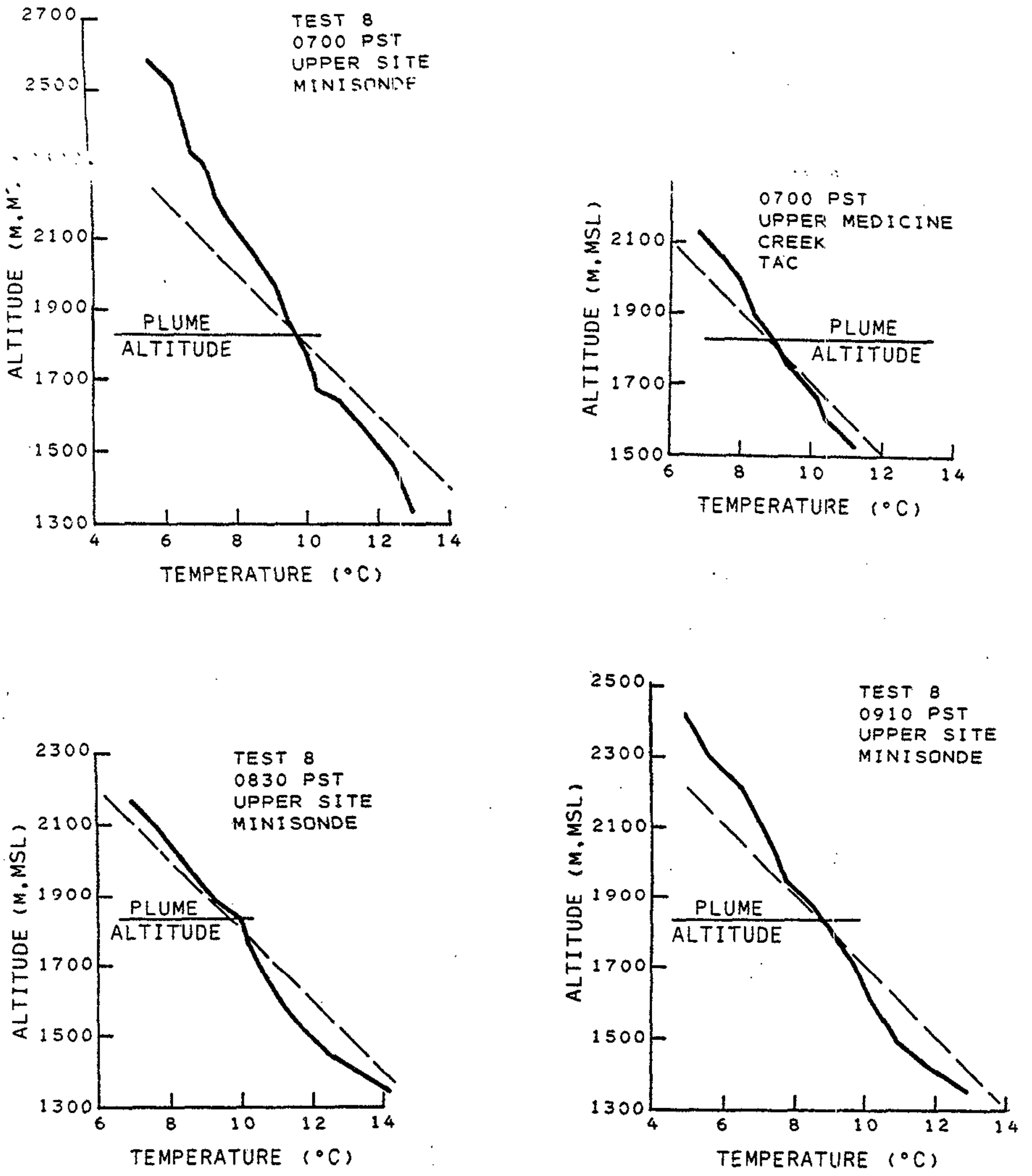


Figure 4.8-2 (Cont'd.)

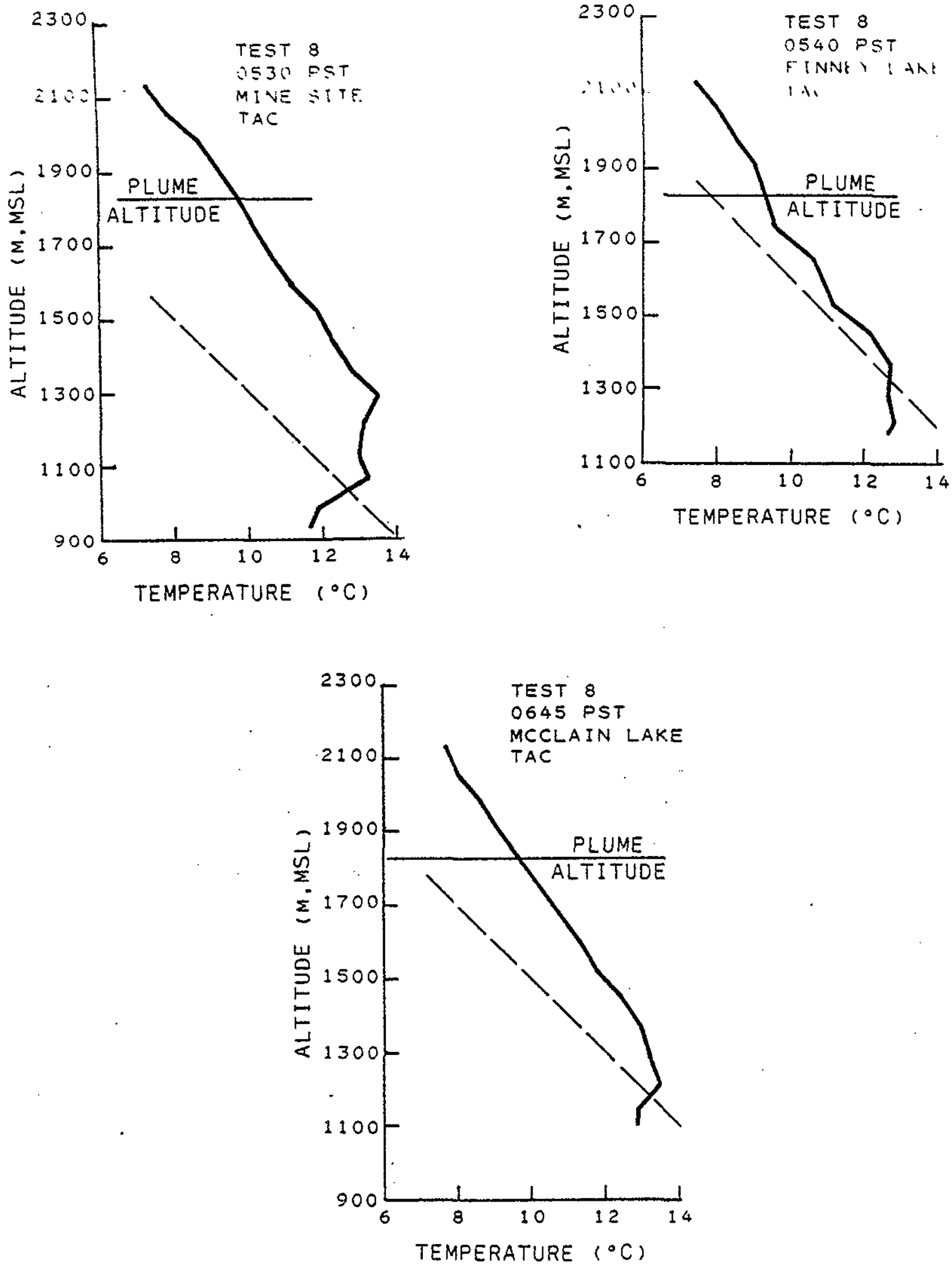


Figure 4.8-2 (Cont'd.)

The surface wind data for this test are presented in Volume 2, Field Data. Low lying sites indicate a well-defined diurnal circulation. The change in flow directions from down-to up-valley occurred at about 0800 PST. Average wind speeds were fairly light and remained under 3 m/s. Higher level sites showed northeasterly flow at about 6 m/s.

The winds aloft data can be seen in the wind direction and wind speed time sections, Figures 4.8-3 and 4.8-4. These show north to northwest flow at release altitude throughout the test. Speeds increased from 3.5 m/s at the beginning of the release to 6 m/s by 0800. The influence of the diurnal flow regime is evident as a slight verr in wind directions favoring the up-valley circulation component together with a wind speed minimum at about 0800-0900 PST.

4.8.3 <u>Tracer Dissemination, Test 8</u>. The tracer release parameters for Test 8 are given in Table 4.8-1, below.

Table 4.8-1 Duration and source strength of tracer release number 8.

Location: Upper Site
Altitude: 1830 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0528	0628	18,720	5.20
Oil Fog (1)	0528	0604	109,800	50.8
Oil Fog (2)	0618	0628	N/A	N/A

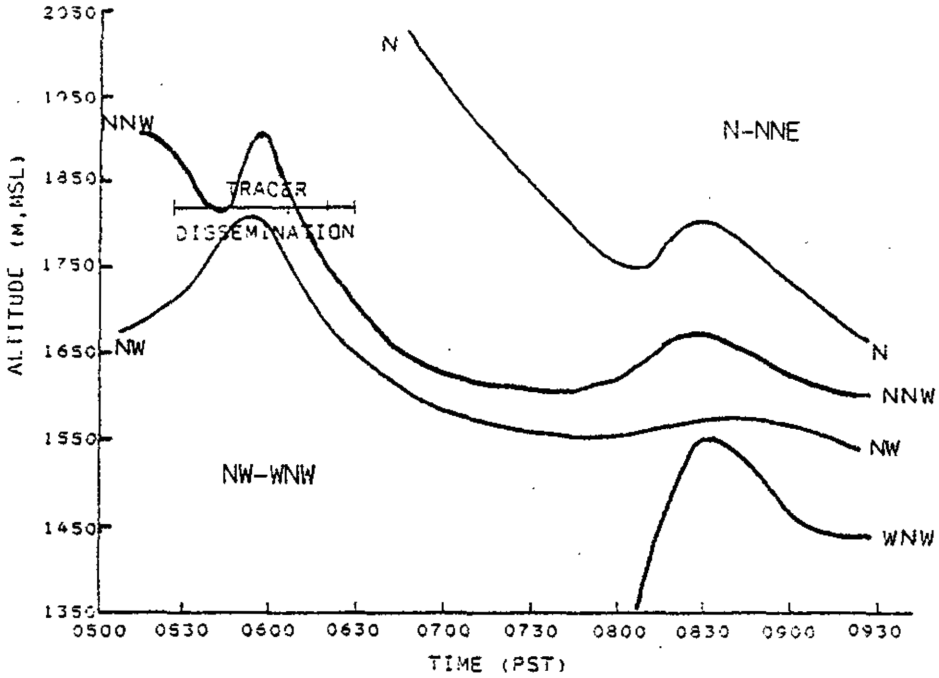


Figure 4.8-3 A time vs. altitude display of wind directions aloft measured during Test 8. Speeds are given in m/s.

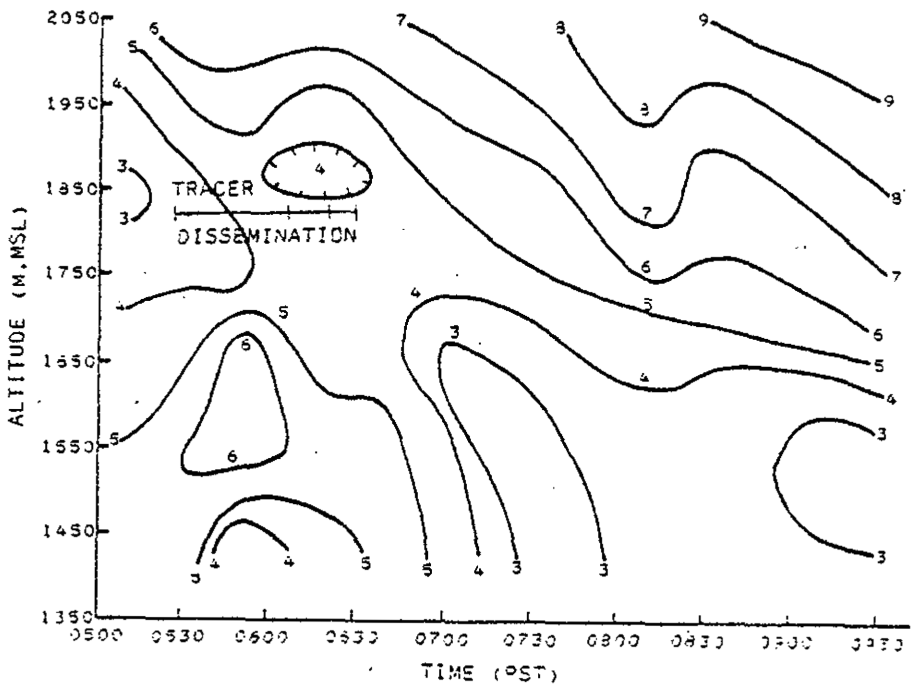


Figure 4.8-4 A time vs. altitude display of wind speeds aloft measured during Test 8. Speeds are given in m/s.

4.8.4 <u>Visual and Photographic Observations</u>. The oil-fog plume was transported toward the south-southeast initially at about 3.5 m/s. Figure 4.8-5 shows that by 0541 PST, 13 minutes after the test began, the leading edge of the plume was over Medicine Creek. Transport shifted more to the southeast and east after that. At about 0600 PST, the leading edge of the plume split, with part of the plume continuing southeast over Upper Medicine Creek and the other part drifting eastward toward McLean and Cornwall Creeks (Figure 4.8-6). That part over Medicine Creek was eventually obscured by scud, but the other part of the plume remained visible and continued to the east and then southeast. Figure 4.8-7 shows the diffuse plume near ground level about 2 to 3 km west of the Ashcroft airstrip at 0647 PST. Terrain elevations in that area are about 1000 m below the plume release height. Plume outlines at selected times are shown in Figure 4.8-8.

4.8.5 <u>Aerial Oil-Fog Measurements</u>. Oil-fog measurements for Test 8 consist of two sets of crosswind passes flown 3.4 and 8.2 km downwind of the release as shown in Figure 4.8-9.

Measurements made during the first set of passes (0550-0607 PST) showed a maximum concentration, equivalent to 16,492 μgm^{-3}, at an altitude of 1770 m MSL. The concentration vs. distance plot for the 1770 m pass, as well as the altitude vs. maximum concentration plot for this set, are shown in Figure 4.8-10. Although time limitations precluded defining the centerline altitude or concentration, calculations of σ_y, σ_z, and $\frac{X\bar{u}}{Q}$ have been made with the available data and are presented in Figures 4.8-11 and 4.8-12. The dispersion coefficients indicate a stable atmosphere value for σ_y and a neutral type value for σ_z. The value of $\frac{X\bar{u}}{Q}$ indicates a neutral dilution rate at the centerline.

A second set of crosswind passes was made between 0619 and 0627 PST over the divide between Medicine and Cornwall Creeks.

Figure 4.8-5 Photo, Test 8. The leading edge of the plume is over the center of Medicine Creek in this view looking east at 0541 PST. Harry Lake is visible left center.

Figure 4.8-6 Photo, Test 8. The plume can be seen splitting in this 0600 PST photo. View is towards the northwest with the source left background. Transport is towards the observer.

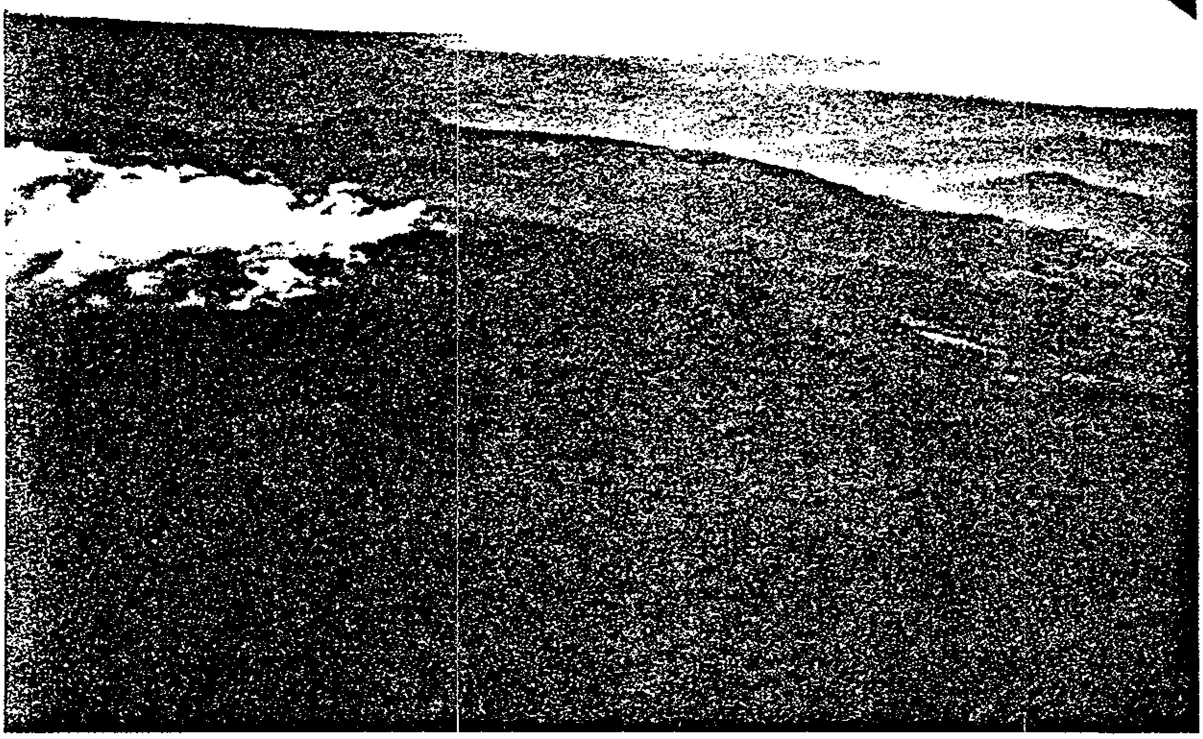


Figure 4.8-7 Photo, Test 8. The diffuse plume can be seen near ground level 2 to 3 km. west of Ashcroft airstrip. View is towards the north, 0647 PST.

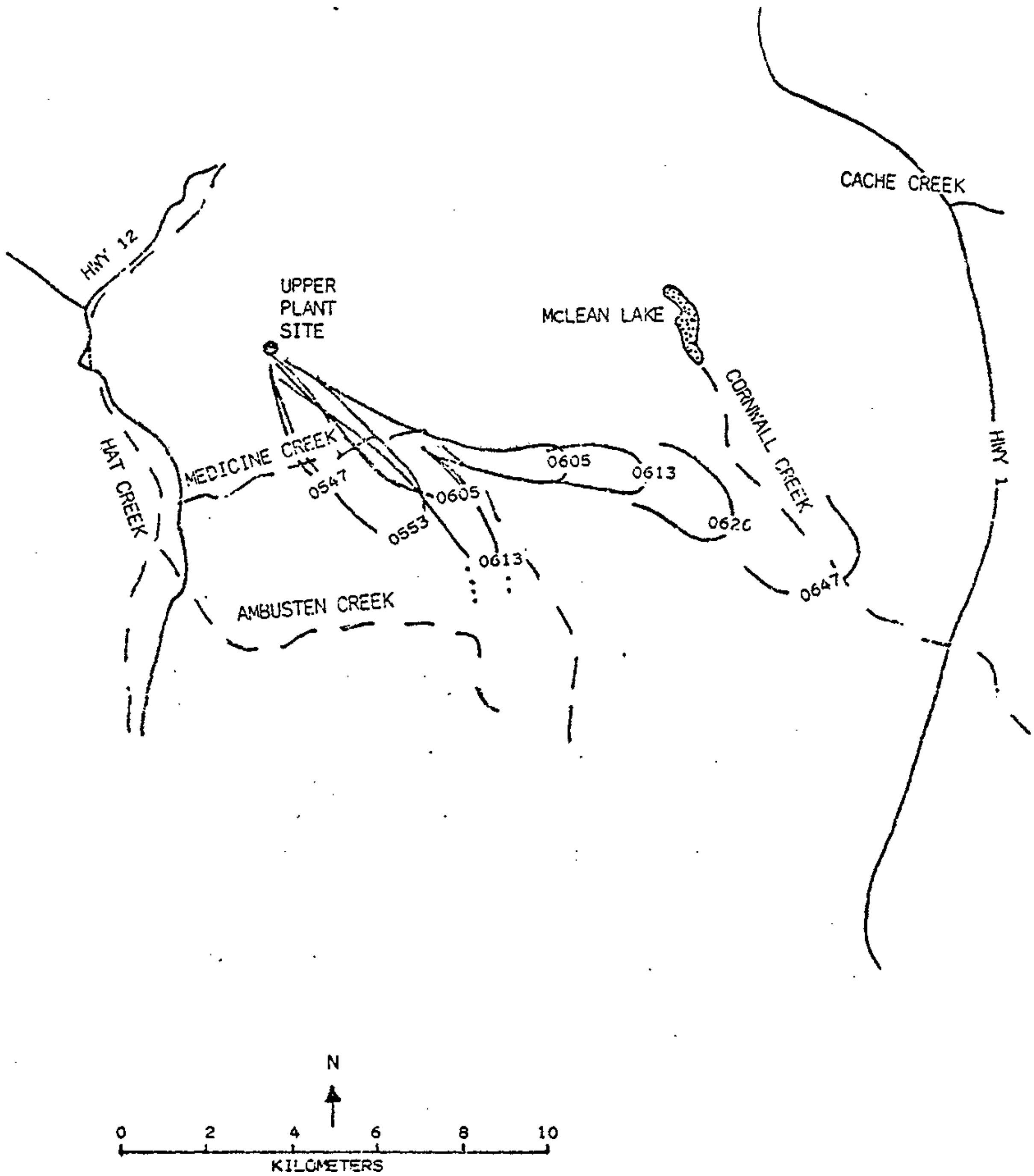


Figure 4.8-8 Plume outlines at selected times during Test 8.

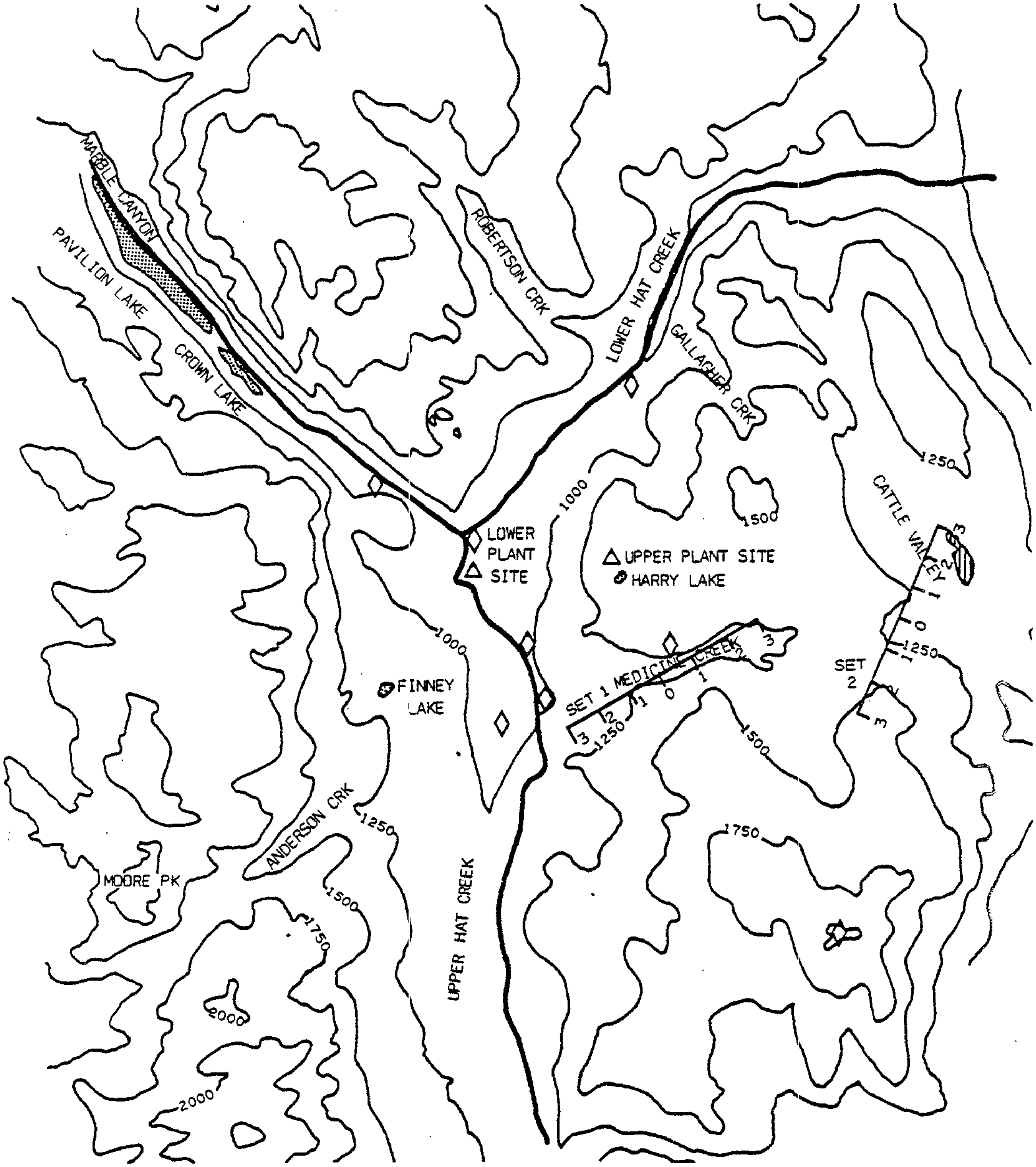


Figure 4.8-9 Locations of oil-fog crosswinds, Test 8. Distances are in kilometers.

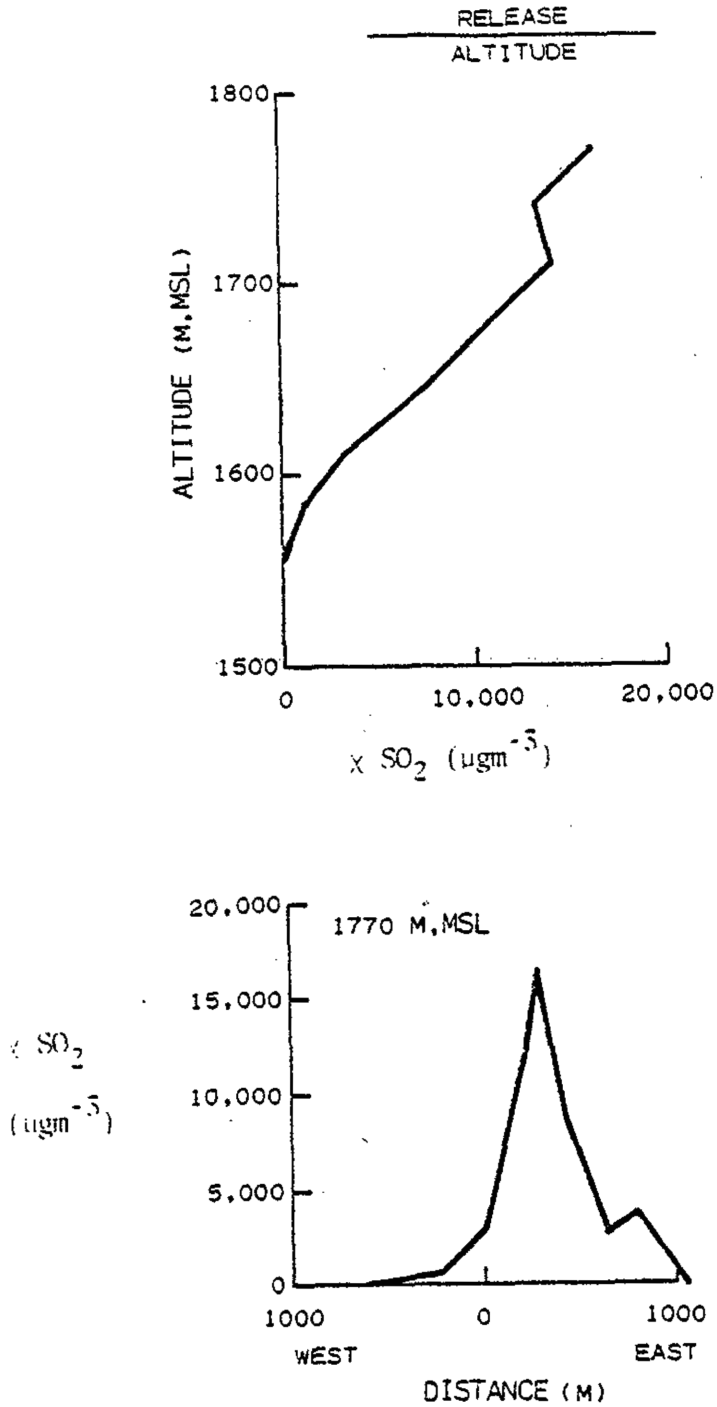


Figure 4.8-10 Horizontal and vertical plume centerline distributions, Test 8, Set 1.

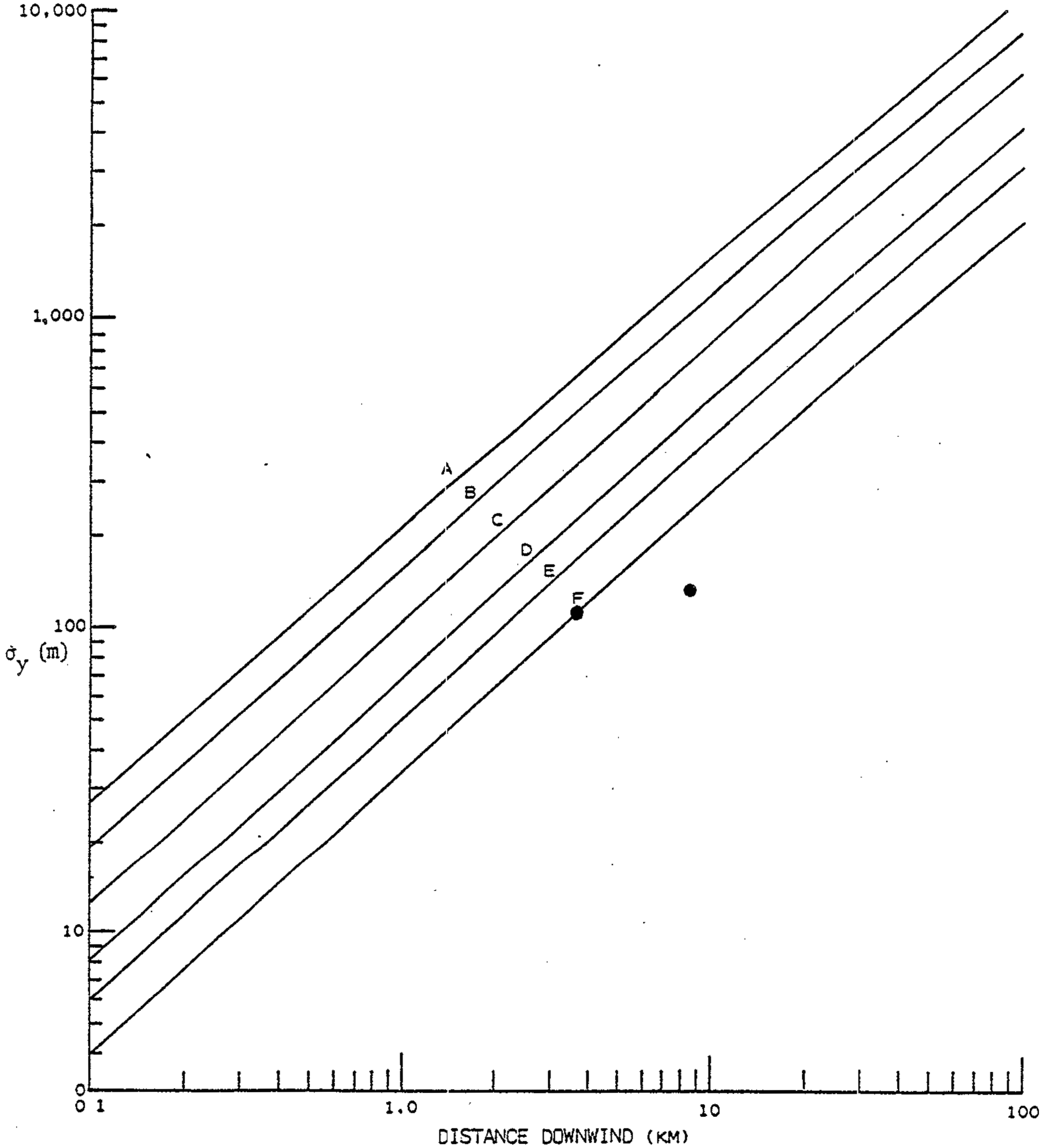


Figure 4.8-11 Measured values of σ_y and σ_z vs. distance, Test 8.

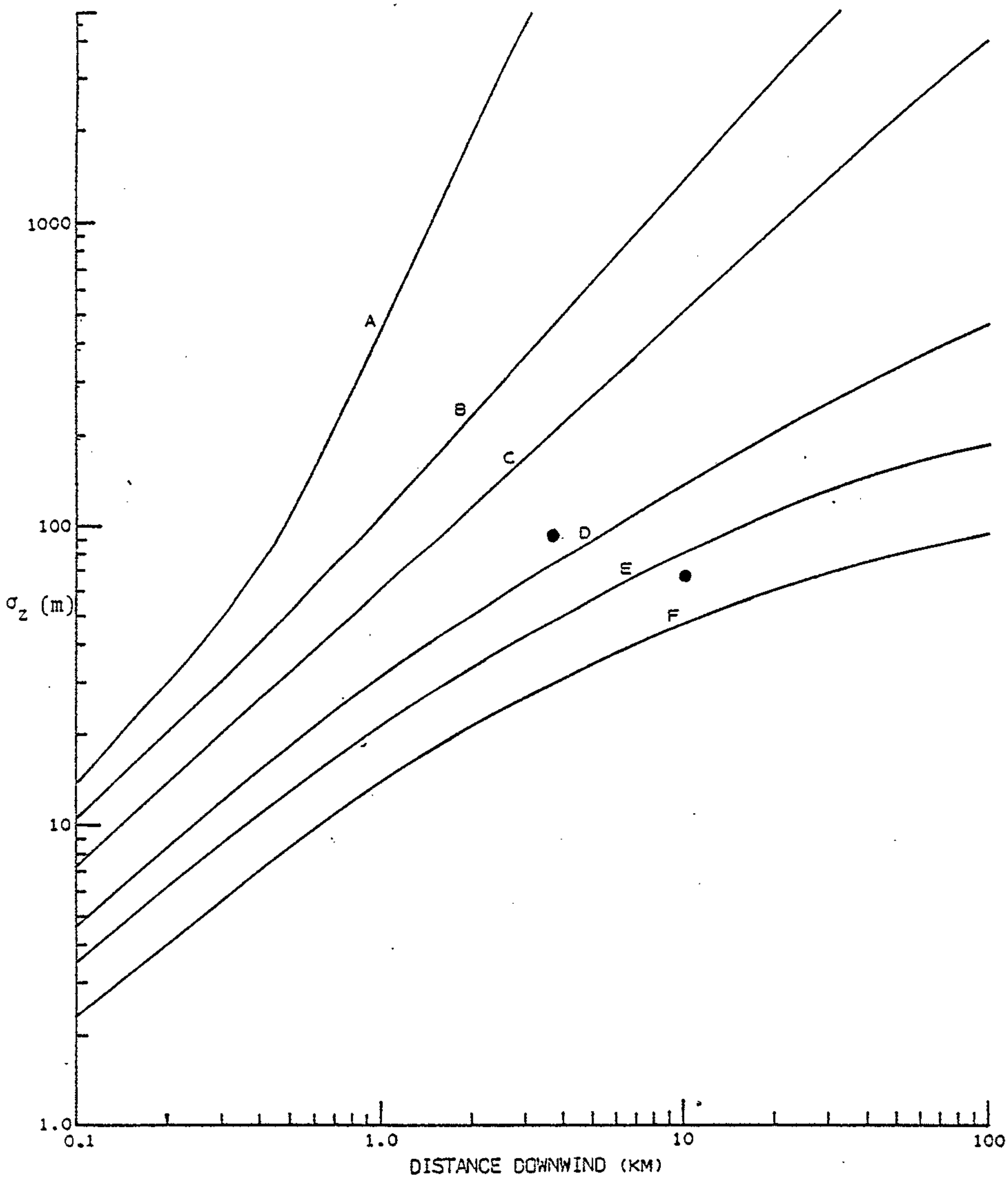


Figure 4.8-11 (Cont'd.)

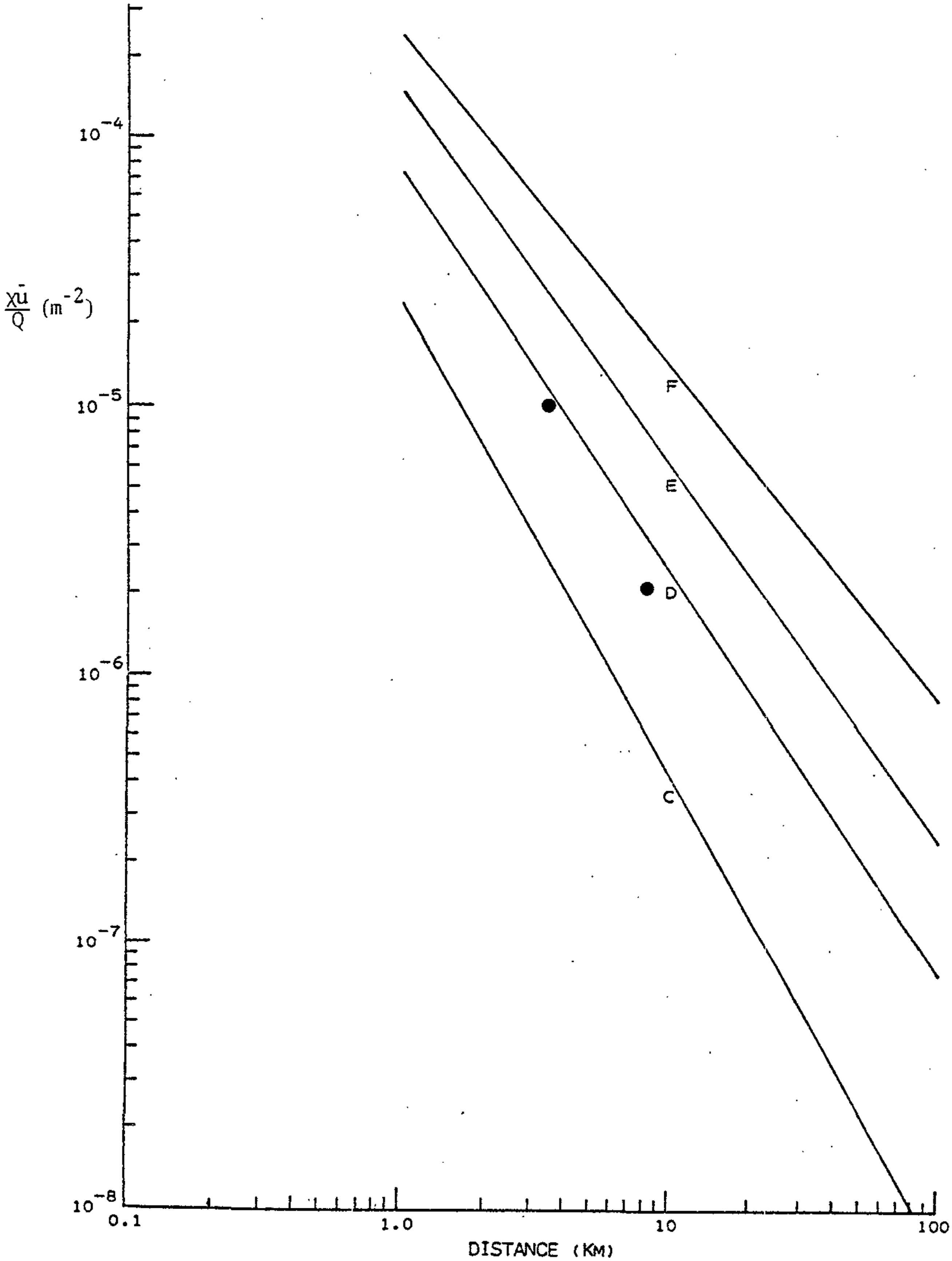


Figure 4.8-12 Measured values of $\frac{\chi\bar{u}}{Q}$ vs. distance, Test 8.

The maximum concentration of 3359 μgm^{-3} was found at 1830 m MSL. A plot of distance vs. concentration for this pass and a plot of altitude vs. maximum concentration for the entire set are given in Figure 4.8-13. It can be seen that while horizontal spreading has been somewhat limited, vertical mixing has apparently been more effective. The estimated values of σ_y and σ_z appear in Figure 4.8-11. The value of $\frac{X\bar{u}}{Q}$, plotted in Figure 4.8-12, indicates continued neutral dispersion.

One of the passes at this location, at 1860 m MSL, extended far enough to the south to measure the portion of the split plume which traveled south, up Medicine Creek. Measurable concentrations of oil-fog were found between 3.0 and 3.4 km southwest of the centerline (reference is to distance scale in Figure 4.8-9), with a maximum measured concentration of 611 μgm^{-3}. There is a saddle in the ridgeline at this location which is at least 150 m below the surrounding high ground. The plume apparently exited Medicine Creek drainage through here and continued out over the Thompson River Gorge.

4.8.6 <u>Aerial SF_6 Measurements</u>. Six aerial samples were taken during the test, and the locations are shown in Figure 4.8-14. Sample data is given in Table 4.8-2. These samples were taken at altitudes of 60 m AGL in a transect from McLean Lake, down Cornwall Creek to the Ashcroft airstrip. Only sample 8H1, from McLean Lake, showed measurable SF_6 with a concentration of 375 μgm^{-3}.

4.8.7 <u>Surface SF_6 Measurements</u>. SF_6 samplers were deployed near Lower and Upper Medicine Creek, on the ridges forming the Upper Medicine Creek Valley, and near the Ashcroft airstrip as shown in Figure 4.8-15. No SF_6 was detected at any of these sites, as the sampling data in Table 4.8-3 shows.

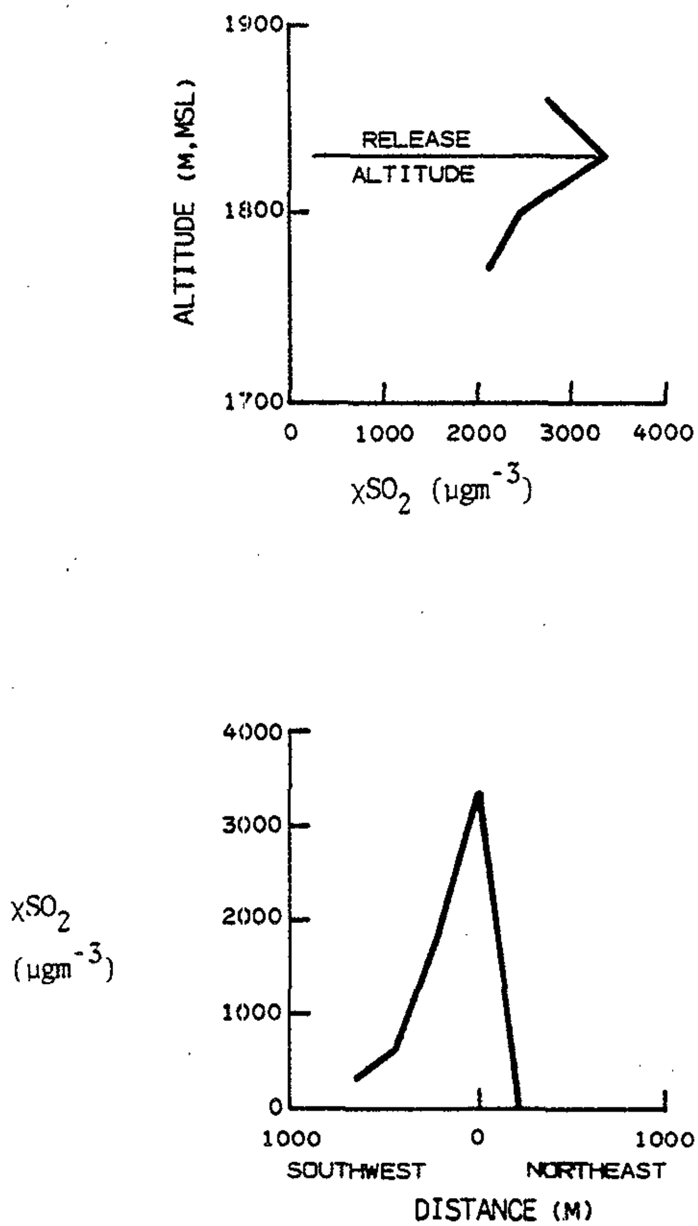


Figure 4.8-13 Horizontal and vertical plume centerline distribution, Test 8, Set 2.

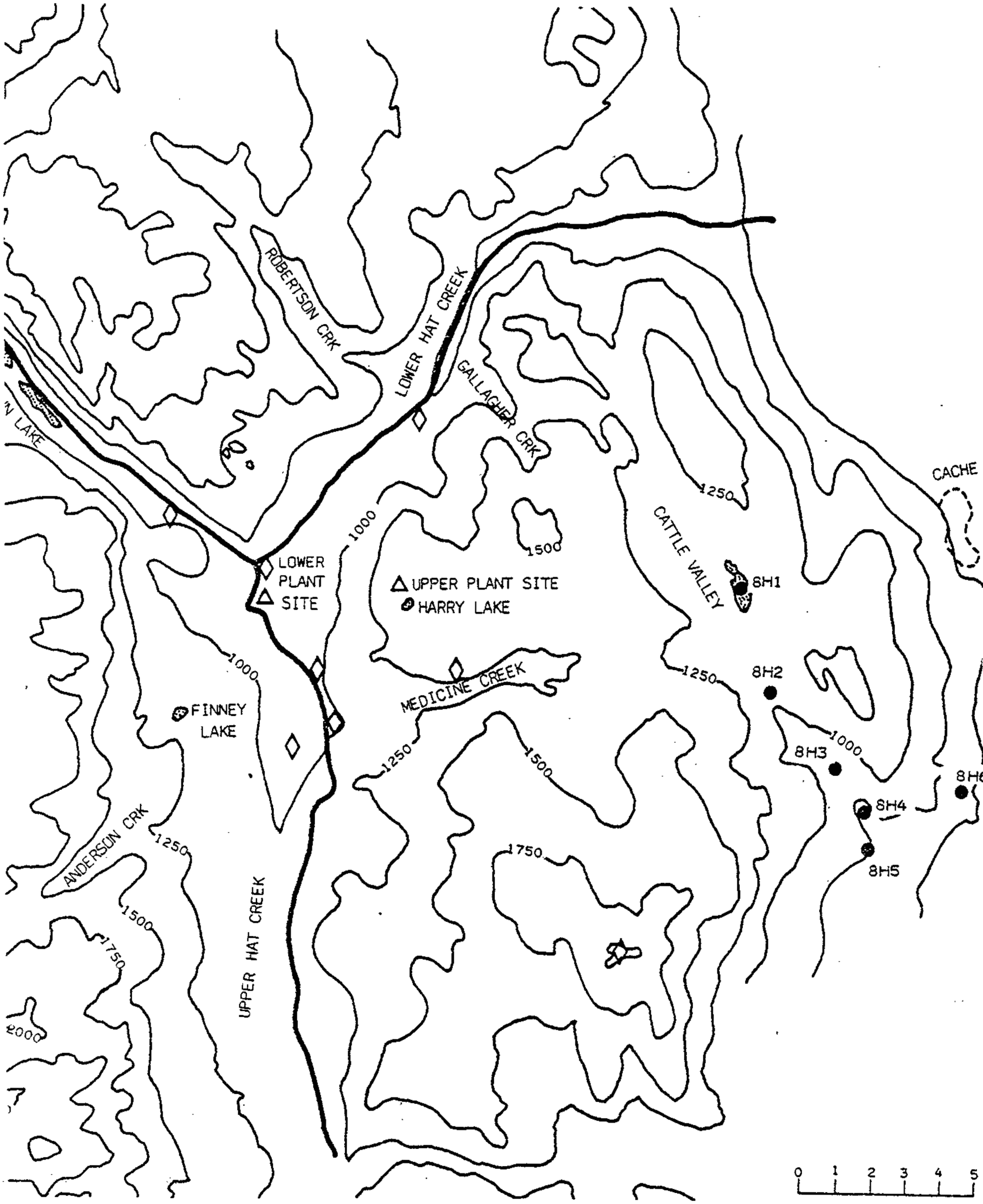


Figure 4.8-14 Location of aerial SF_6 samples, Test 8.

Table 4.8-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	Altitude (m) AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
8H1	9.9	1281	60	0605	1	375	483
8H2	11.2	1100	60	0610	1	0	0
8H3	12.8	975	60	0621	1	0	0
8H4	14.8	855	60	0633	1	0	0
8H5	15.0	795	60	0649	1	0	0
8H6	18.2	610	60	0705	1	0	0

Table 4.8-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On (PST)	Time Off (PST)	Sampling Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
8S1	7.5	1280	0529	0559	30	0	0
			0559	0629	30	0	0
8S1A	16.1	765	0700	0730	30	0	0
			0730	0800	30	0	0
			0800	0830	30	0	0
			0830	0900	30	0	0
			0900	0930	30	0	0
			0930	1000	30	0	0
8S2	0.9	1450	0532	0602	30	0	0
			0602	0632	30	0	0
			0632	0702	30	0	0
			0702	0732	30	0	0
			0732	0802	30	0	0
			0802	0832	30	0	0
			0920	0945	25	0	0
8S3	7.2	1645	0558	0628	30	Malf.	-
			0628	0758	30	0	0
			0658	0728	30	0	0
			0728	0758	30	0	0
			0758	0828	30	0	0
			0828	0858	30	Malf.	-

Table 4.8-3 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
8S4	6.4	1325	0510	0540	30	Malf.	-
			0540	0610	30	0	0
			0610	0640	30	0	0
			0640	0710	30	0	0
			0710	0740	30	0	0
			0740	0810	30	Malf.	-
			0930	0949	19	0	0
8S5	5.9	1770	0517	0547	30	0	0
			0547	0617	30	<20	<26
			0617	0630	13	0	0
8S5A	10.2	1235	0655	0725	30	0	0
			0725	0755	30	0	0
			0755	0825	30	0	0
			0825	0855	30	0	0
			0855	0925	30	0	0
			0925	0955	30	0	0
8S6	8.0	1525	0524	0554	30	0	0
			0554	0624	30	0	0
			0624	0654	30	<20	<26
8S6A	19.0	655	0706	0736	30	0	0
			0736	0806	30	0	0
			0806	0836	30	0	0
			0836	0906	30	0	0
			0906	0936	30	0	0
			0936	1006	30	0	0
8S7	8.3	1435	0601	0800	119	0	0
			0800	1000	120	0	0
8S8	8.9	1645	0606	0752	106	0	0
			0752	0952	120	Malf.	-
8S9	5.4	1280	0610	0757	107	0	0
			0757	0957	120	0	0
8S10	8.0	1435	0620	0755	95	0	0
			0755	0955	120	0	0
8T4	4.5	835	0530	0603	33	0	0
			0603	0700	57	0	0
			0700	0812	72	0	0

Table 4.8-3 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
8T5	4.0	765	0530	0559	28	0	0
8T6	7.0	670	0530	0548	18	0	0
8T7	7.5	840	0625	0730	65	0	0
8T8	11.0	825	0615	0715	60	0	0
8T9	4.0	900	0530	0606	36	0	0
			0606	0708	62	0	0
			0708	0808	60	Malf.	-
8T10	3.8	1000	0619	0650	31	0	0
			0650	0720	30	0	0
8T11	3.0	1190	0635	0735	60	0	0
8B	0.0	1375	0500	0600	60	0	0
			0600	0700	60	0	0
			0700	0800	60	0	0
			0800	0900	60	0	0
			0900	1000	60	0	0

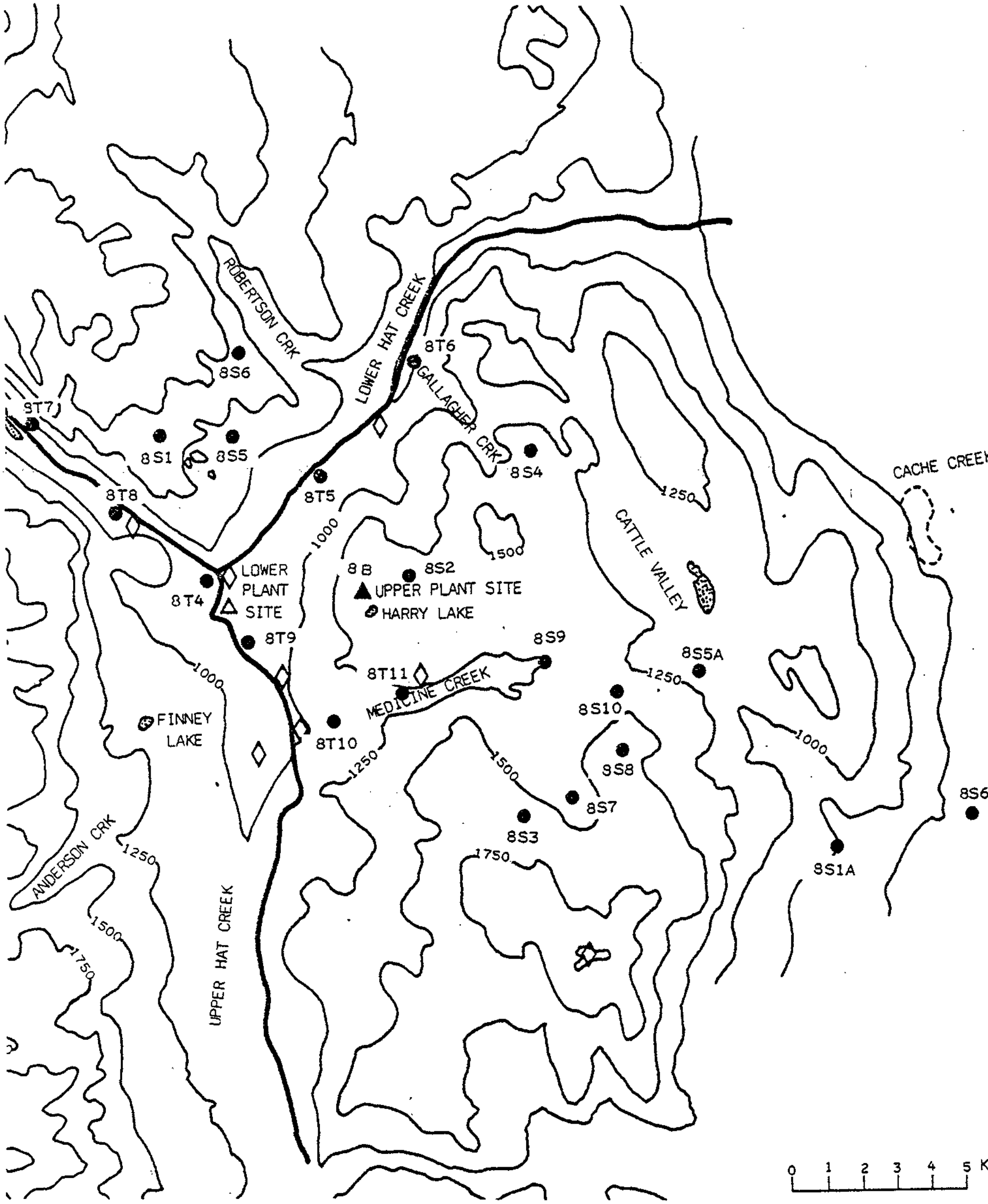


Figure 4.8-15 Location of surface SF_6 samplers, Test 8.

4.8.8 Turbulence Measurements. The turbulence data available for Test 8, plotted in Figure 4.8-16, comes from the two sets of oil-fog crosswind patterns (see map, Figure 4.8-9). The data from Set 1 show rates of turbulence dissipation associated with a neutral atmosphere and a gradual trend to increase with decreasing altitude. Intermittence values were rather low, indicating a uniform turbulence regime, though a slight trend to increase at lower altitudes is evident. These measurements indicate that more turbulent conditions existed at lower altitudes, probably reflecting a shallow valley circulation below the gradient wind level.

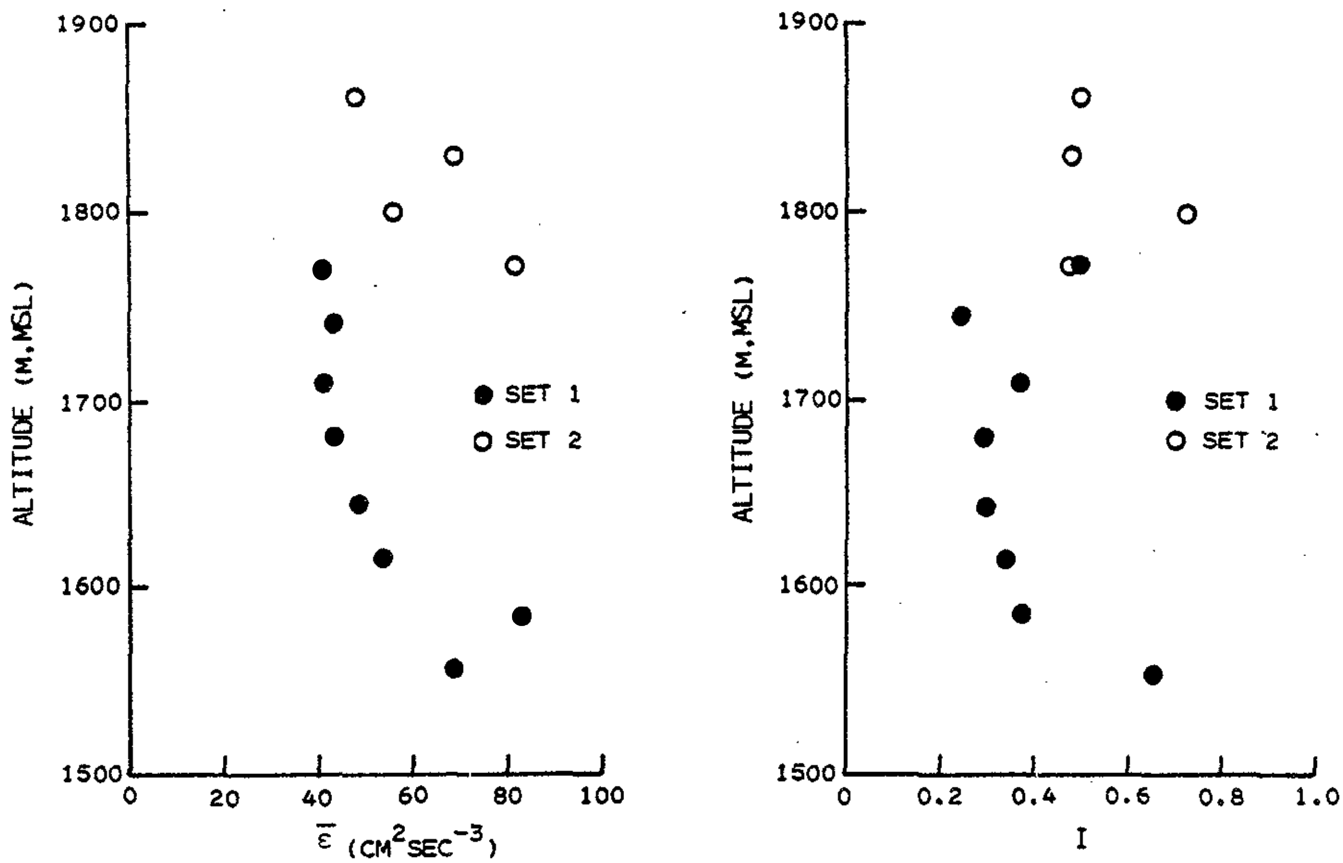


Figure 4.8-16 Turbulence measurements, Test 8.

The data from Set 2 show greater turbulence than Set 1, probably reflecting the lower AGL altitudes, and consequently more intense mechanical turbulence at this location. The values indicate a C-D dispersion regime. These data also suggest increasing turbulence with decreasing altitude. Intermittence values were similar to those from Set 1 and showed no apparent trend with altitude.

4.8.9 Summary of Test 8. The Test 8 tracer plume was released from the upper plant site at an altitude of 1770 m MSL. A stack height of 183 m was assumed. Winds at plume altitude were from the northwest at 3 to 4 m/s. Stability conditions were near neutral. Upon release, the plume spread up Medicine Creek and split. The main portion of the plume crossed eastward into the Cornwall Creek drainage, while the other portion continued south up Medicine Creek and crossed to the east at a saddle just south of SF_6 sampler 8S8. The main portion of the plume continued out over the Ashcroft area and dispersed.

There was no measurable surface impact during this test, though samplers were strategically placed along the ridgelines. Aerial SF_6 measurements revealed a maximum concentration of 375 μgm^{-3} 60 m above the Ground at McLean Lake.

Oil-fog measurements show the plume spread vertically rather rapidly, though the centerline apparently remained near release altitude as far as the divide between Medicine and Cornwall Creeks. The normalized concentrations show near-neutral dispersion rates. Turbulence dissipation rates were characteristic of neutral to slightly unstable dispersion regimes. The data suggest the rather uniform turbulence structure characteristic of mechanical (terrain) effects and neutral lapse rates.

In summary, Test 8 may be classed as a neutral plume whose transport was greatly influenced by the terrain. However, a combination of favorable dispersion conditions prevented measurable surface impact.

4.9 Test Number Nine, August 6, 1976

Test 9 was conducted at the lower plant site during the early afternoon of August 6, 1976. An assumed stack height of 366 m, with 366 m plume rise gave a release altitude of 1645 m MSL. The test was conducted under conditions suitable for examination of plume behavior during periods of light winds and vigorous convection.

4.9.1 Synoptic Setting for Test 9. The setting for August 6, 1976 was much like that described in Section 4.3.1 for August 5, 1976. The low-level flow over the project area was northerly, although the gradient was very weak. The 500-mb low pressure system remained stationary off the California-Oregon border. During the early afternoon, cloudiness over the project area consisted of scattered to broken cumulus based at 2150 m MSL.

Surface and 700-mb maps are shown in Figure 4.9-1.

4.9.2 Meteorological Parameters for Test 9. Temperature soundings from around the test area were provided by the NAWC tracer aircraft. Winds aloft measurements were made from the lower site, using double tracked pilot balloons. Surface wind data are available from the B. C. Hydro meteorological station network.

The four temperature soundings taken during this operation are reproduced in Figure 4.9-2. These show essentially dry adiabated lapse rates prevailed through a deep layer extending from near the surface to at least 2100 m MSL. Superadiabatic conditions were found in the lowest 100 m.

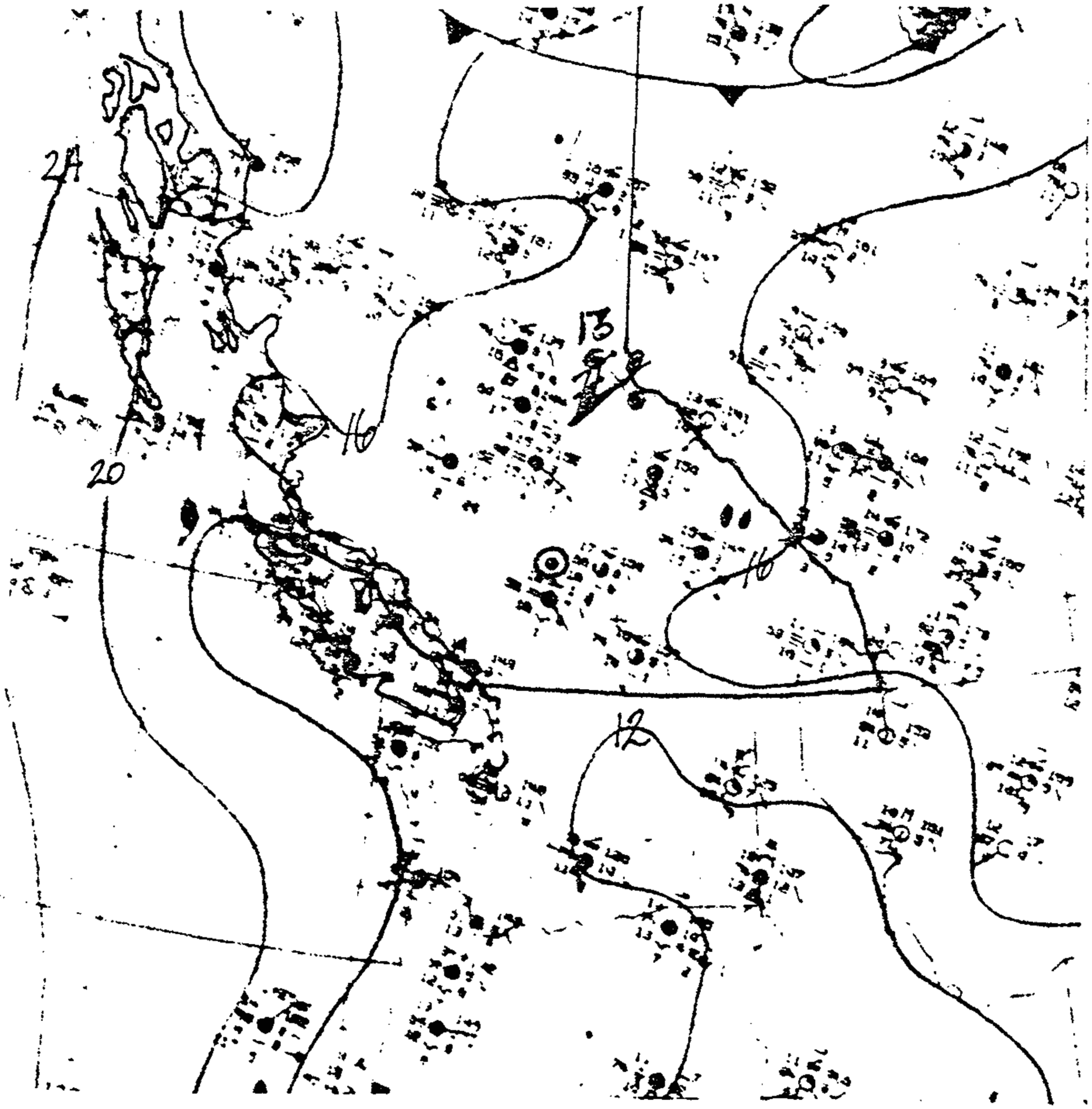


Figure 4.9-1 Surface and 500 mb charts for Test 9,
August 6, 1976, 0400 PST.

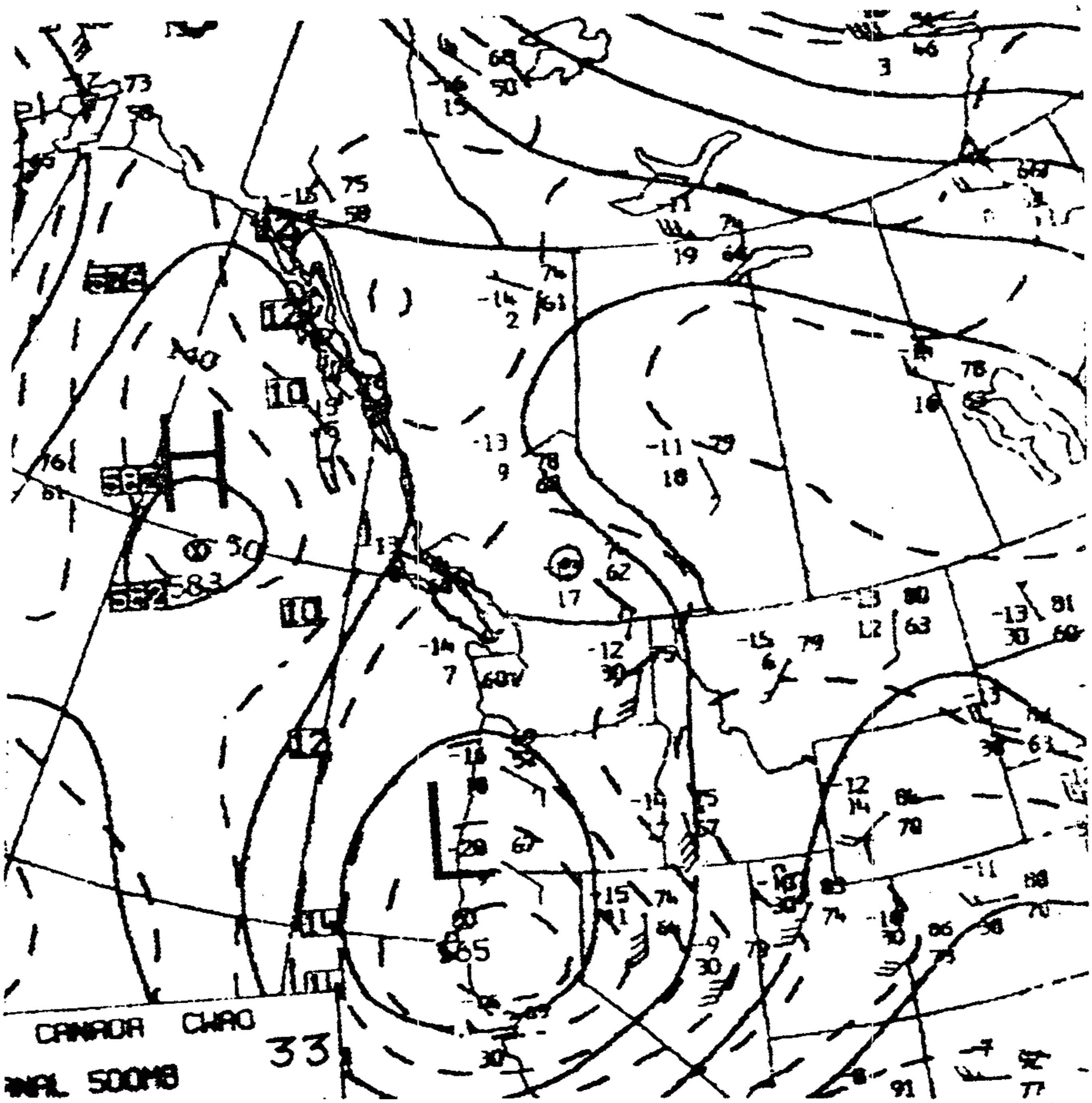


Figure 4.9-1 (Cont'd)

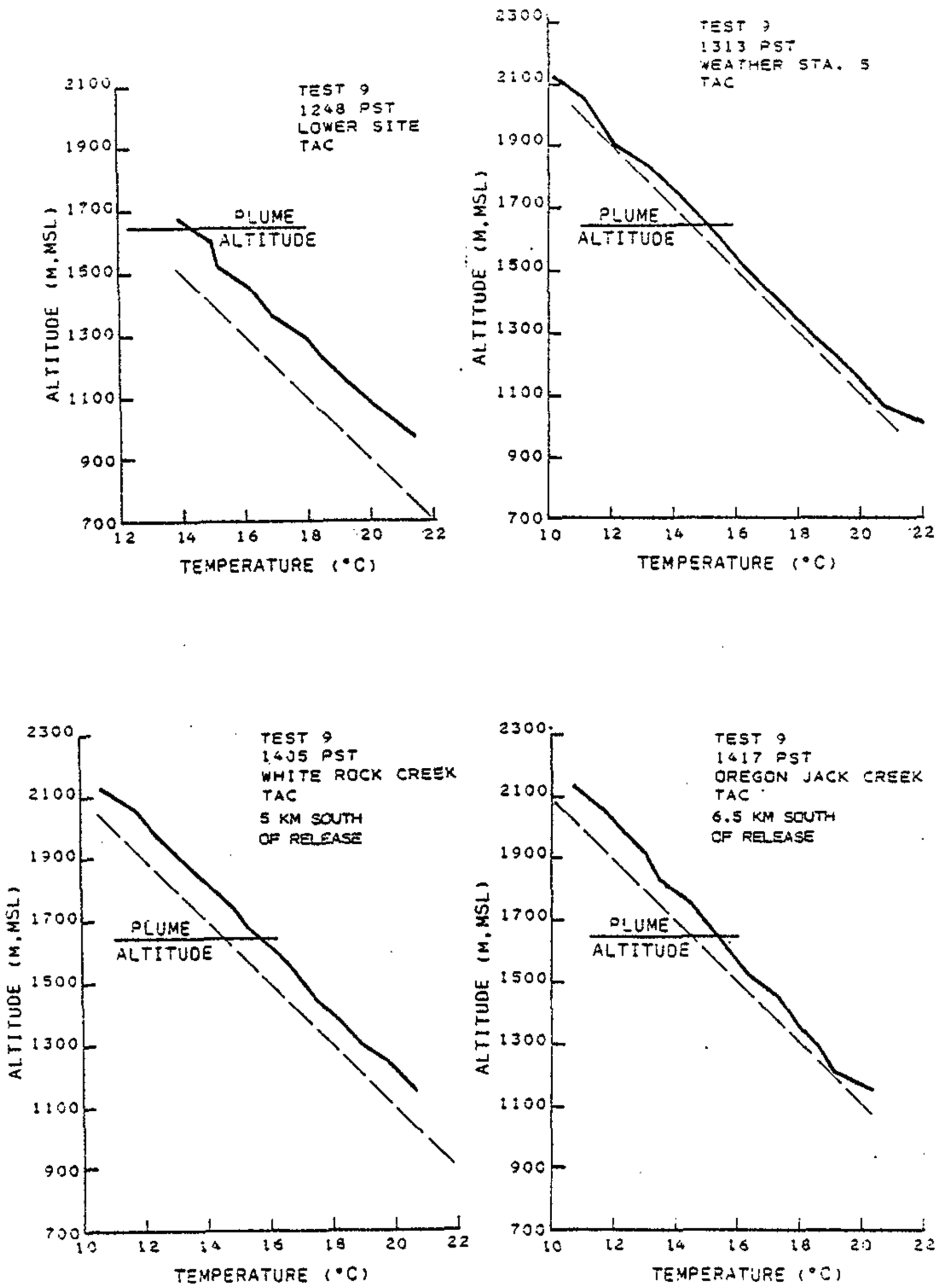


Figure 4.9-2 Vertical temperature profiles measured during Test 9.

The surface wind data from this test are available in Volume 2, Field Data. The available data show a well-developed up-valley circulation at all sites during the test. Mean wind speeds were less than 2.5 m/s.

The winds aloft time sections are shown in Figure 4.9-3 (direction) and 4.9-4 (speed). It can be seen that the winds at plume altitude were variable in direction (though the plume moved slowly south and west) with speeds less than 1 m/s. Lower level winds were also highly variable, and were generally less than 2 m/s.

4.9.3 Tracer Dissemination, Test 9. The tracer release parameters for Test 9 are contained in Table 4.9-1, below.

Table 4.9-1 Duration and source strength of tracer release number 9.

Location: Lower Site
Altitude: 1645 m MSL
Simulated Stack Height: 366 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	1302	1402	18,396	5.11
Oil Fog (1)	1302	1344	109,800	43.6
Oil Fog (2)	1354	1402	N/A	N/A

4.9.4 Visual and Photographic Observations. This looping plume release clearly demonstrated the predominance of vertical rather than horizontal plume transport. During the first fifteen minutes, transport was mostly upward, while the smoke drifted slowly to the west. Downward transport prevailed during the next fifteen to twenty minutes. Figure 4.9-5 shows, at 1341 PST or

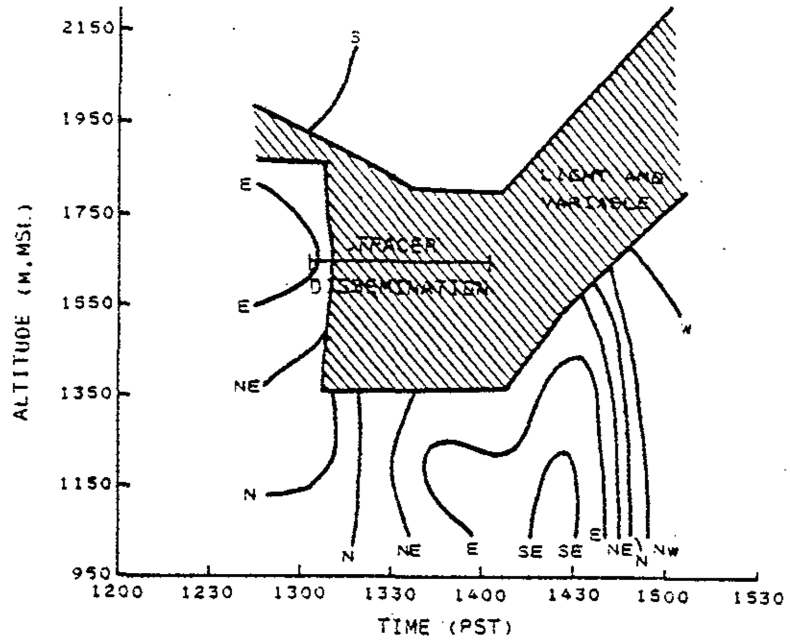


Figure 4.9-3 Time vs. altitude display of wind directions aloft measured during Test 9. Speeds are given in m/s.

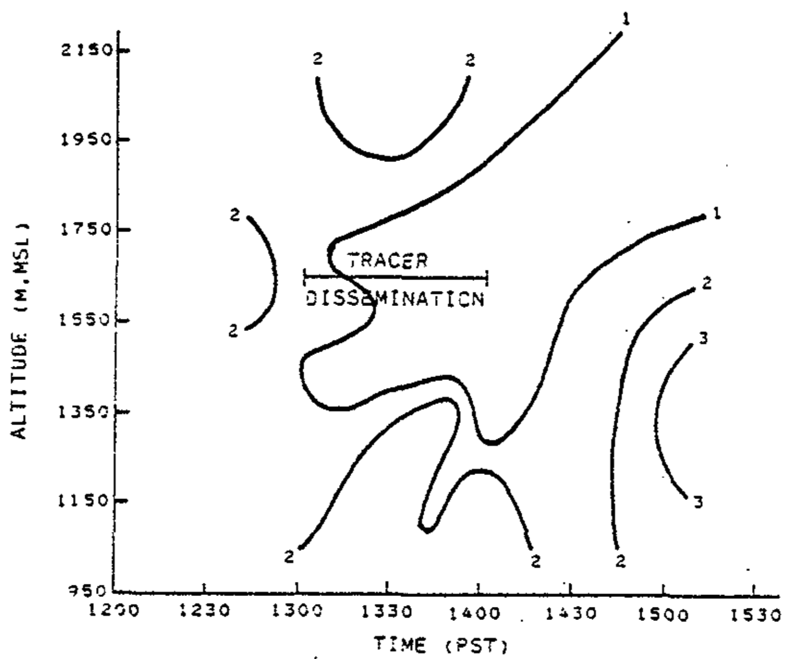


Figure 4.9-4 Time vs. altitude display of wind speeds aloft measured during Test 9. Speeds are given in m/s.

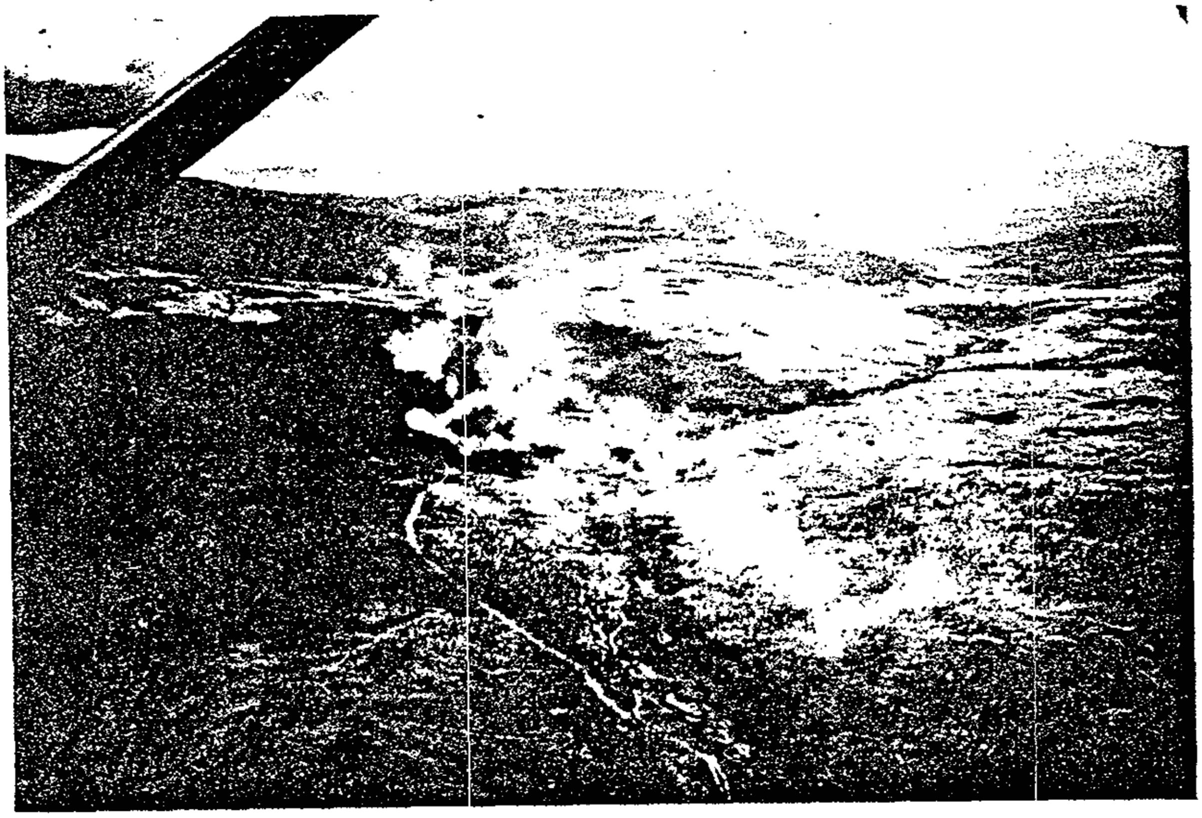


Figure 4.9-5 The oil-fog just being released is rising while earlier portions of this looping plume are visible well below release altitude. View is towards the south-southeast at 1341 PST.

39 minutes after the release began, that the smoke just being released was rising, while plume remnants below the release level were visible just west of the release site. The plume was invisible nine minutes after the release ended.

Plume outlines were not possible to draw due to frequent loops, but Figure 4.9-6 shows the general area occupied by the plume.

4.9.5 Aerial Oil-Fog Measurements. One set of crosswind passes were made during this test at the location shown in Figure 4.9-7, about 3 km downwind. Fourteen separate passes were flown at altitudes between 1675 and 1100 m MSL from 1328-1400 PST. The maximum concentration of 2831 μgm^{-3} was found at the release altitude (1645 m MSL). Figure 4.9-8 presents a plot of distance vs. concentration for the 1645 m pass and a plot of altitude vs.

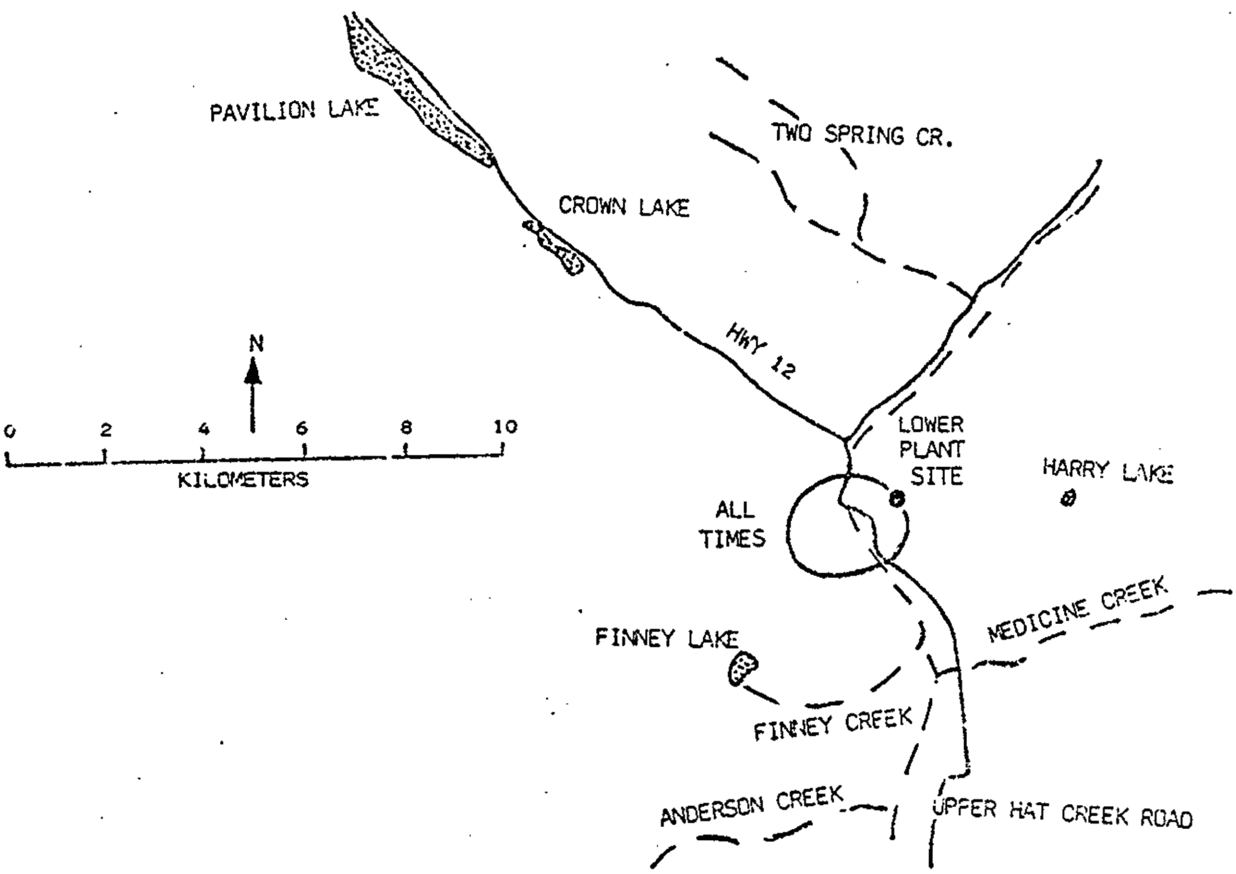


Figure 4.9-6 Plume outlines for Test 9. Times are PST.

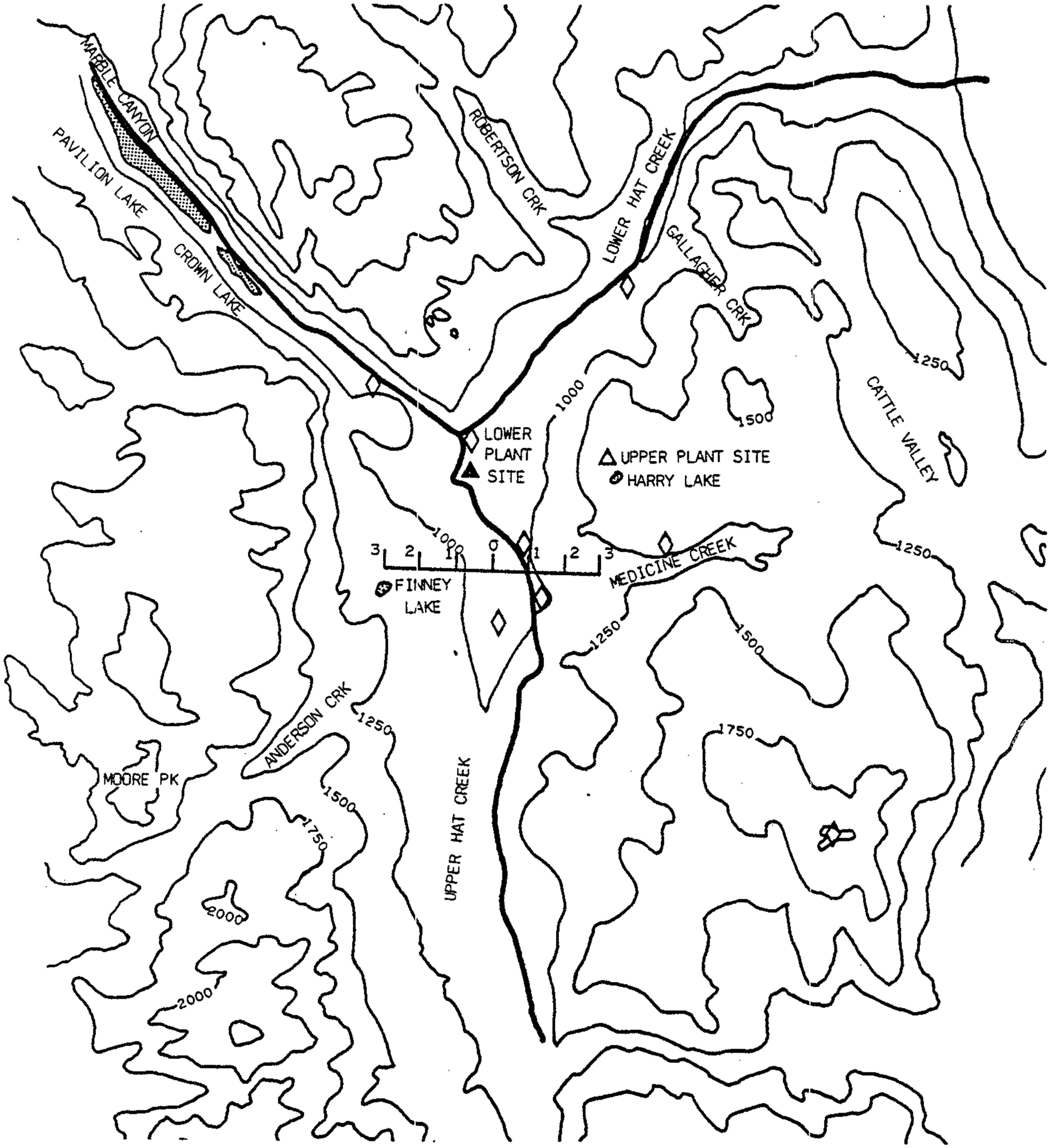


Figure 4.9-7 Location of oil-fog crosswinds, Test 9. Distances are in kilometers.

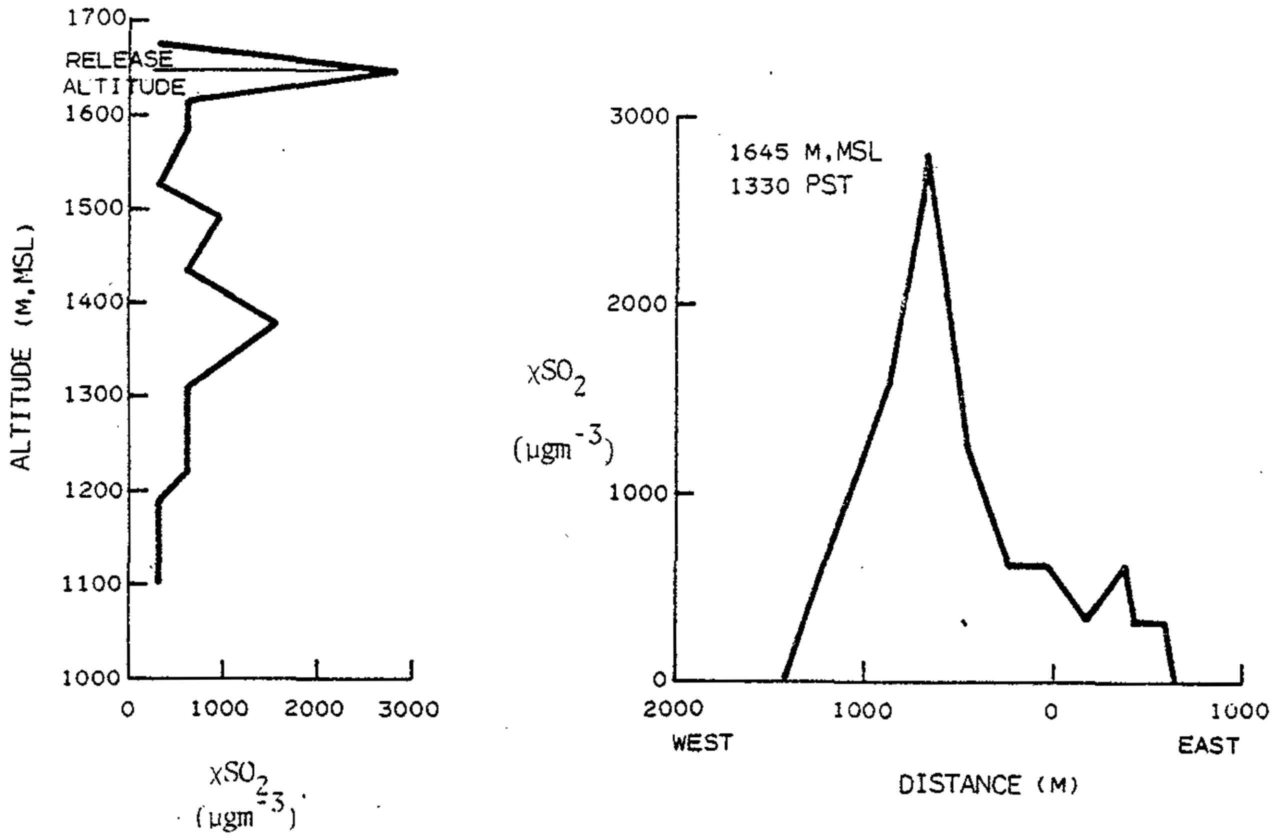


Figure 4.9-8 Vertical and horizontal plume centerline distributions from oil-fog measurements, Test 9.

maximum concentration for the entire set. These distributions show a good deal of spreading, both horizontally and vertically. Concentrations of as high as 315 μgm^{-3} were observed within 100 m AGL. The values σ_y and σ_z have been estimated and are displayed in Figure 4.9-9. Due to the low concentrations measured during most passes and the rapid changes in plume geometry, these measurements are representative only of the data at hand and may not reflect long-term values. The value of $\frac{X\bar{u}}{Q}$, plotted in Figure 4.9-10, indicates rapid dispersion.

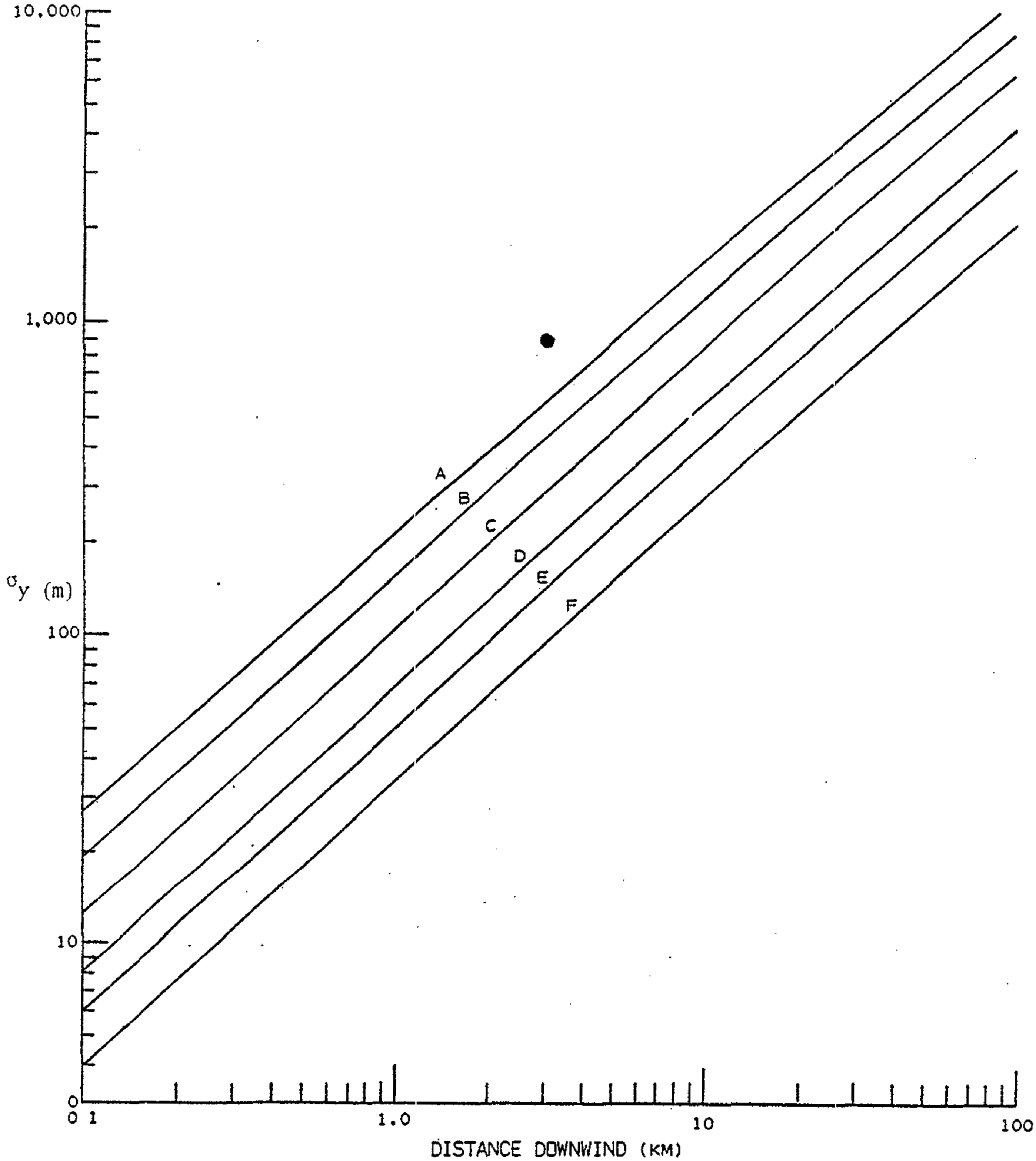


Figure 4.9-9 Measured values of σ_y and σ_z for Test 9.

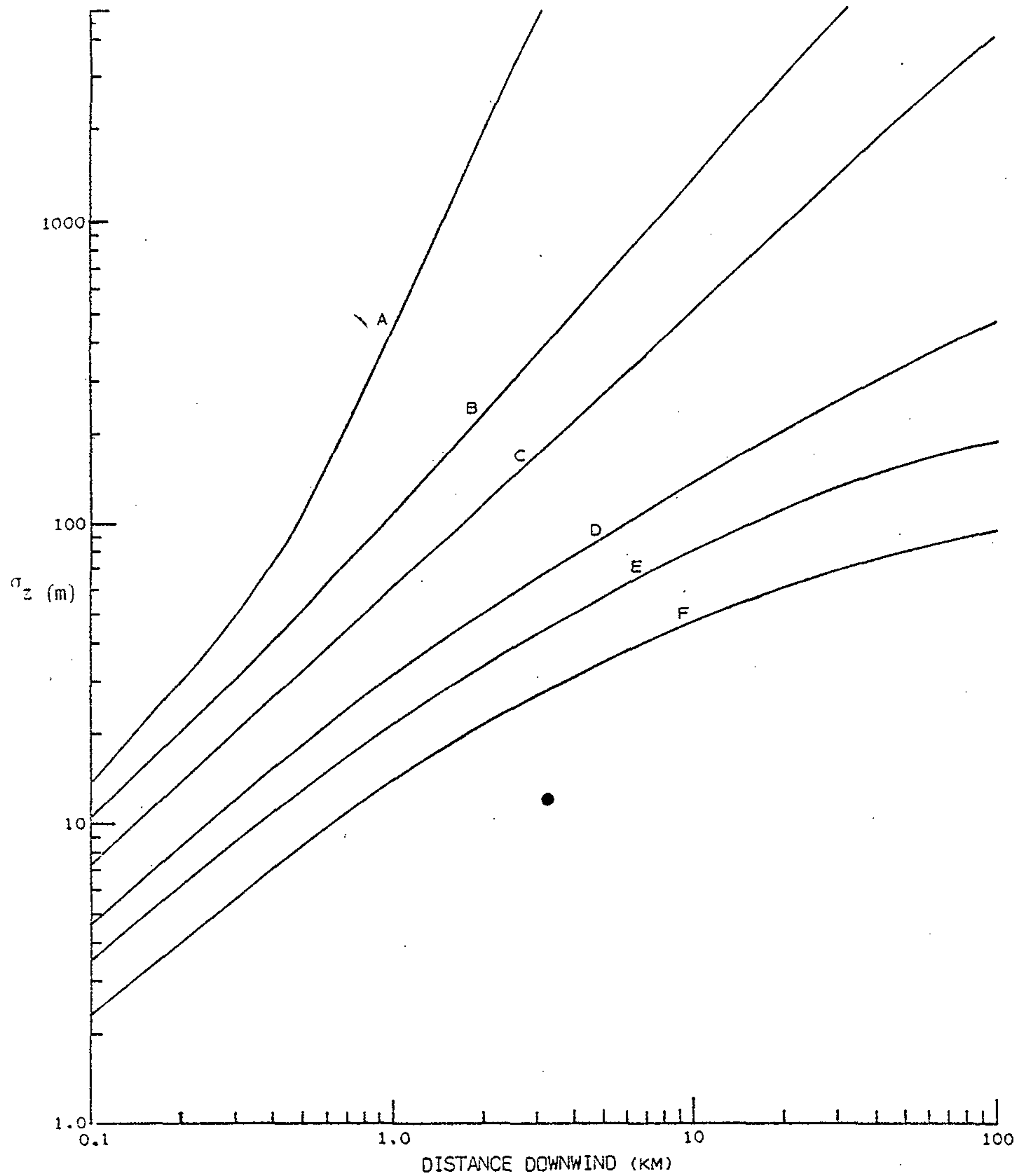


Figure 4.9-9 (Cont'd).

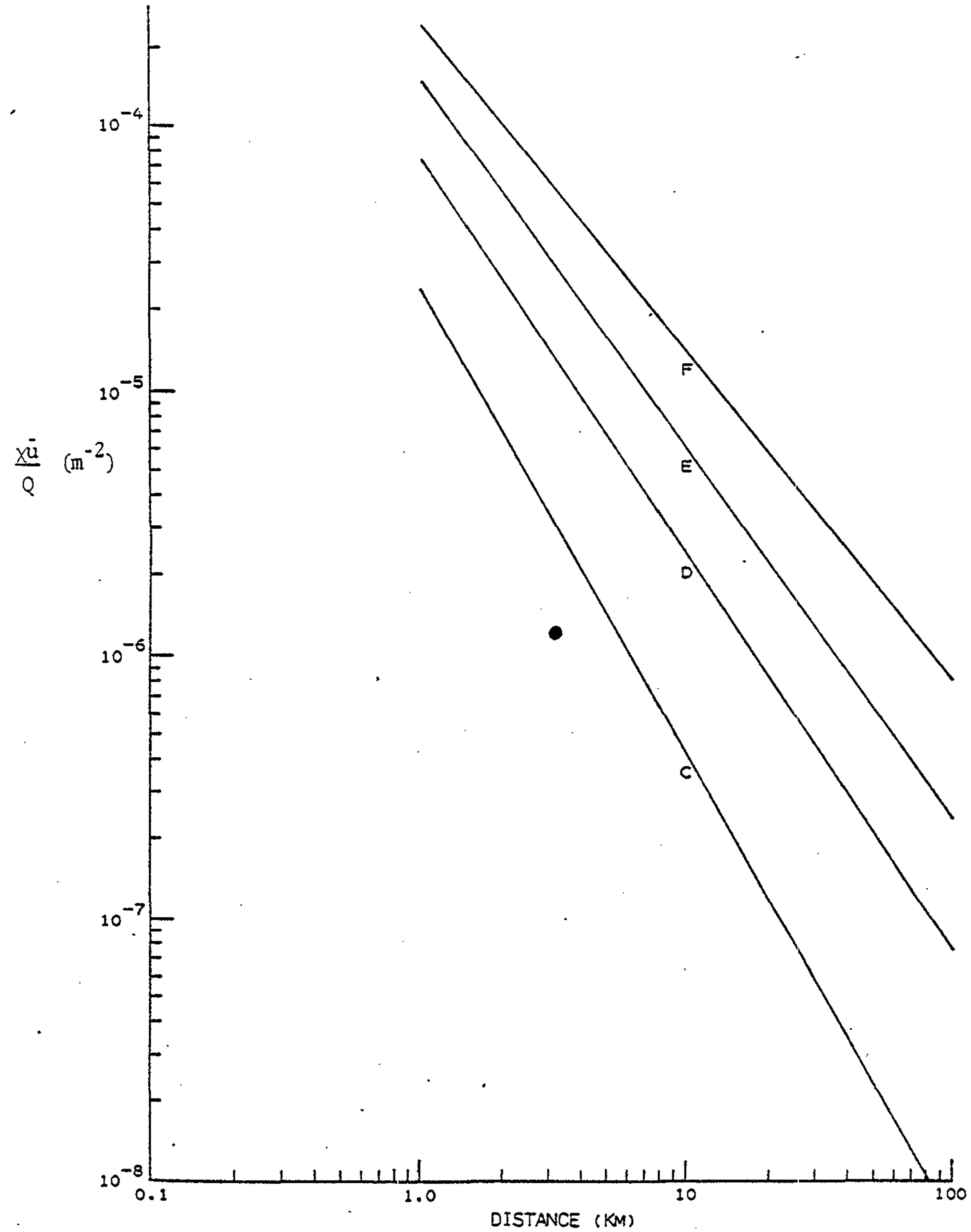


Figure 4.9-10 Measured values of $\frac{\chi\bar{u}}{Q}$ for Test 9.

4.9.6 Aerial SF_6 Measurements. Fourteen aerial SF_6 grab samples were taken during the test. Their locations are shown in Figure 4.9-11 and data listed in Table 4.9-2. The sampling was conducted in the general area of visible ground impact at altitudes of 30 to 370 m AGL. All but one sample contained measurable SF_6, and the maximum aerial concentration was found to be 5352 μgm^{-3}. This was recorded in sample 4H6 taken at an altitude of 60 m AGL near Finney Lake. Other samples contained concentrations ranging from near threshold level (< 22 μgm^{-3}) to 392 μgm^{-3}.

4.9.7 Surface SF_6 Measurements. Sixteen SF_6 samplers were deployed during Test 9 at locations south through west of the lower plant site. These are shown in Figure 4.9-12, and supplementary information is given in Table 4.9-3. Fourteen of these 16 samplers detected measurable amounts of SF_6 in equivalent SO_2 concentrations of as much as 1180 μgm^{-3} (half-hour sample), which was detected at site 4S6, 2.4 km from the release point. In general, the maximum concentrations (> 500 μgm^{-3}) were found to have occurred from Finney Lake eastward to Hat Creek. Maximum hourly average concentrations of 423, 414, and 902 μgm^{-3} were found at sites 4S1, 4S4, and 4S6, respectively. Site 4S8A, on the slopes above Finney Lake, 4.1 km from the plant site, measured 412 μgm^{-3} in a 52-minute sample. Most other sites showed measurable concentrations though one hour values were under 100 μgm^{-3}.

4.9.8 Turbulence Measurements. The turbulence measurements for this test come from the oil-fog crosswind patterns and are presented in Figure 4.8-13. It can be seen that the turbulence values are moderately high and show a slight trend to increase with decreasing height. Intermittence values were moderate and also tended to decrease with altitude. These measurements are indicative of a deep surface-based convection layer with similar turbulence and intermittence regimes throughout.

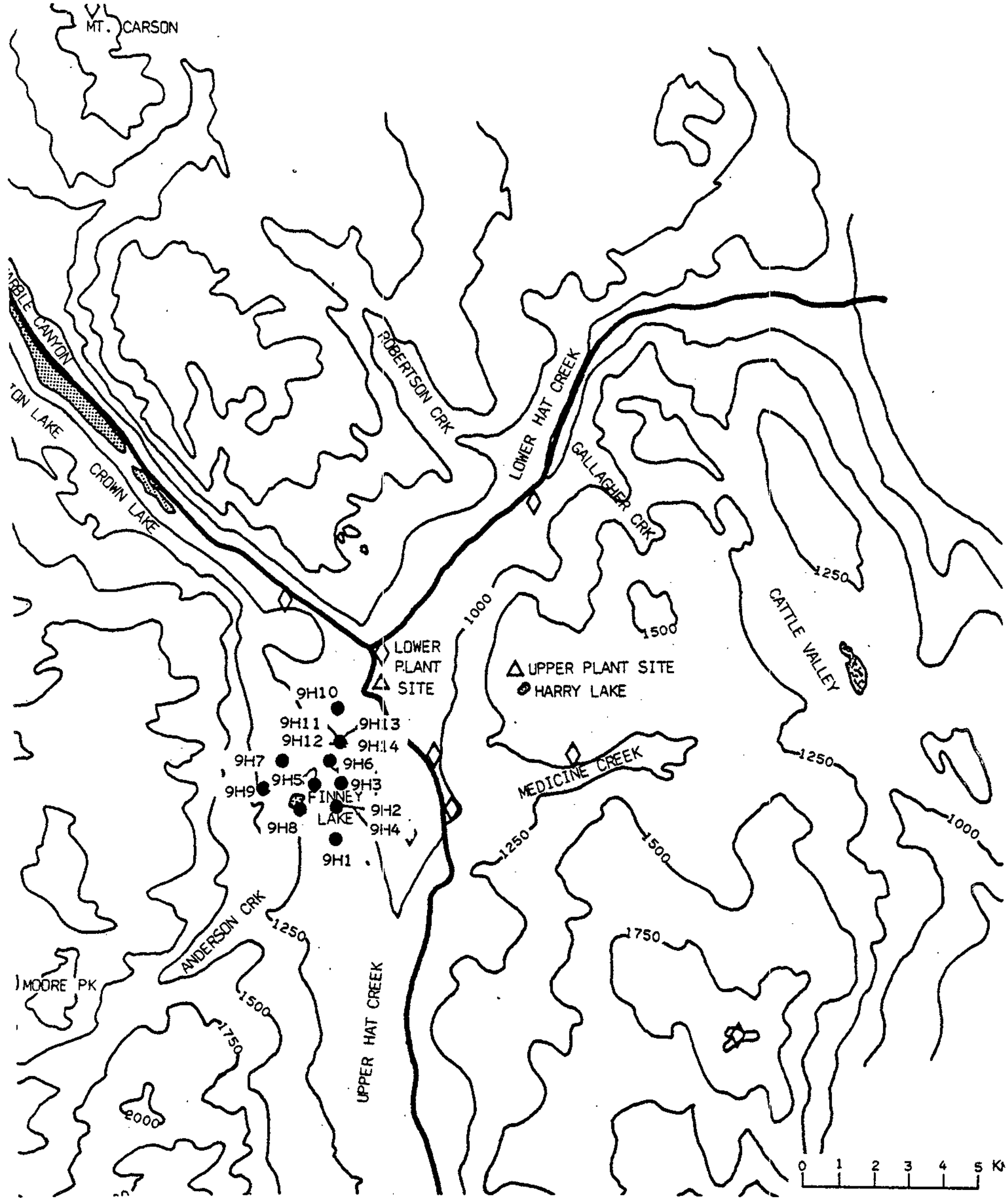


Figure 4.9-11 Location of aerial SF_6 measurements, Test 9.

Table 4.9-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	Altitude (m) AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
9H1	5.0	1220	105	1320	1	68	81
9H2	4.1	1220	105	1323	1	58	69
9H3	3.2	1220	165	1326	1	392	464
9H4	4.1	1220	105	1330	1	46	54
9H5	3.8	1130	60	1335	1	5352	6313
9H6	3.2	1160	90	1337	1	228	270
9H7	4.1	1190	30	1339	1	<22	<26
9H8	4.3	1280	105	1341	1	0	0
9H9	4.8	1160	75	1343	1	88	104
9H10	2.1	1130	140	1345	1	30	36
9H11	2.5	1130	90	1347	1	144	170
9H12	2.5	1220	180	1349	1	122	144
9H13	2.5	1310	275	1351	1	80	95
9H14	2.5	1405	370	1355	1	294	348

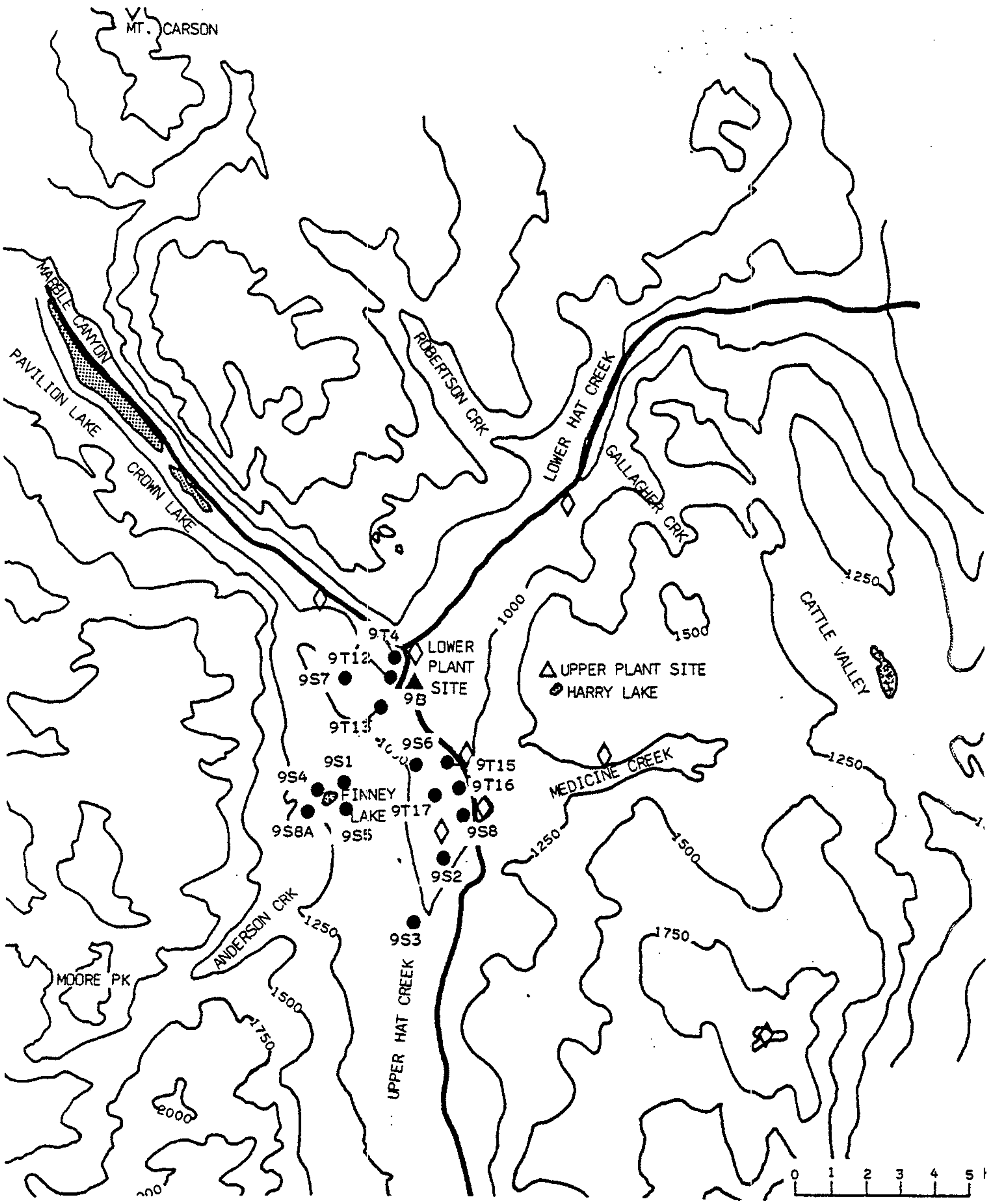


Figure 4.9-12 Location of surface SF_6 measurements, Test 9.

Table 4.9-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
9S1	3.8	1160	1317	1347	30	0	0
			1347	1417	30	126	149
			1417	1447	30	682	807
			1445	1517	30	164	194
			1517	1536	19	58	69
9S2	5.0	961	1322	1352	30	<22	<26
			1352	1422	30	164	194
			1422	1452	30	72	85
			1452	1515	23	34	40
9S3	7.0	1037	1326	1356	30	Malf.	-
			1356	1426	30	0	0
			1426	1456	30	Malf.	-
			1456	1513	17	Malf.	-
9S4	4.4	1190	1349	1419	30	110	130
			1419	1449	39	666	788
			1449	1519	30	162	192
			1519	1527	8	228	270
9S5	4.1	1128	1352	1428	36	Malf.	-
			1428	1520	52	122	144
9S6	2.4	946	1356	1426	30	1180	1397
			1426	1456	30	624	739
			1456	1526	30	198	234
9S7	2.1	900	1400	1435	35	<22	<26
			1435	1500	25	58	69
9S8	3.8	946	1405	1421	16	0	0
9S8A	5.1	1220	1431	1523	52	412	488
9B	0.0	915	1300	1330	30	34	40
			1330	1400	30	88	104
			1400	1430	30	68	81
			1430	1500	30	54	64
9T4	4.5	833	1320	1345	35	0	0
			1415	1443	28	0	0
			1443	1506	23	30	36

Table 4.9-3 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
9T12	1.1	854	1300	1325	25	0	0
			1325	1348	23	0	0
			1348	1415	27	<22	<26
			1415	1445	30	0	0
			1445	1504	19	<22	<26
9T13	0.9	968	1325	1350	25	0	0
			1350	1421	31	0	0
			1421	1448	27	<22	<26
9T15	1.9	884	1300	1326	26	0	0
			1326	1400	34	0	0
			1400	1430	30	0	0
			1430	1455	25	64	76
9T16	2.8	915	1300	1328	28	0	0
			1328	1348	20	0	0
			1348	1434	46	0	0
			1434	1452	28	34	40
9T17	2.6	991	1335	1404	29	0	0
			1404	1440	36	38	44
			1440	1500	20	80	95

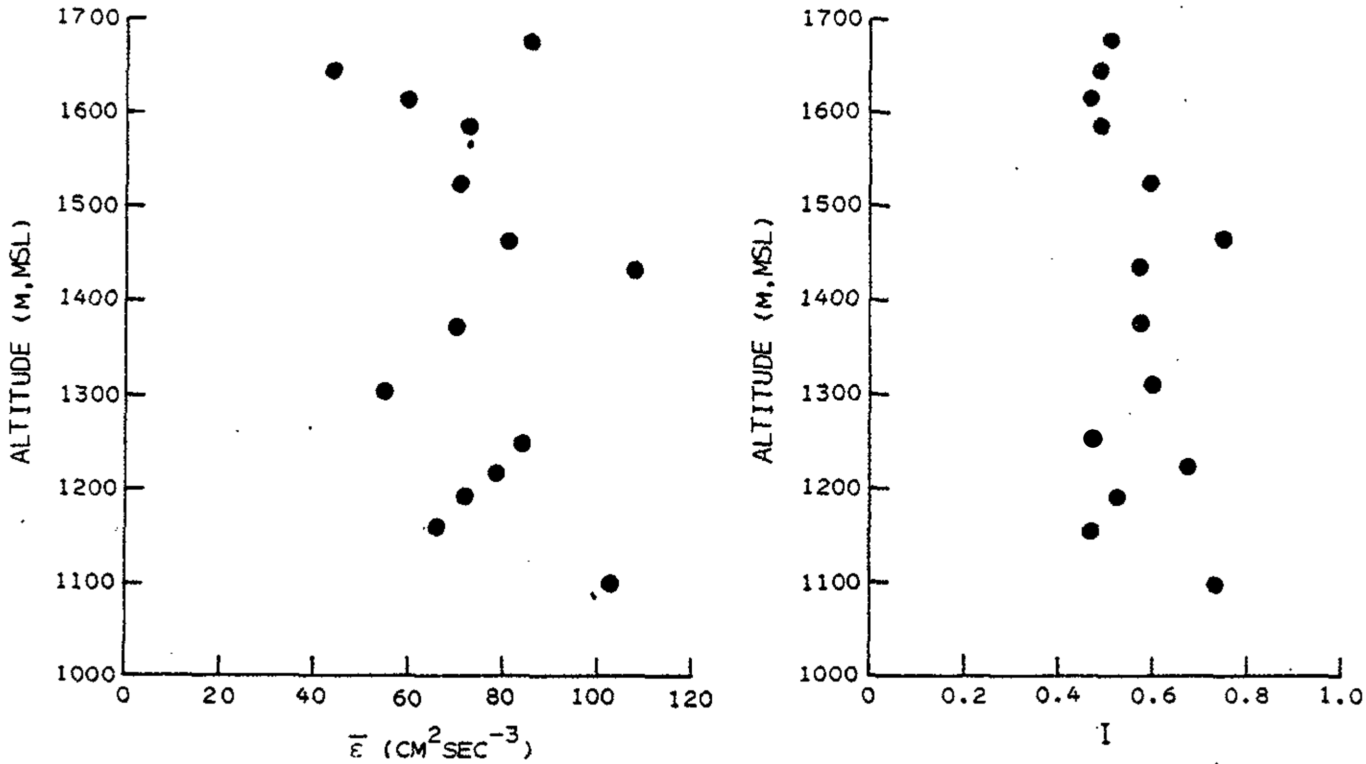


Figure 4.9-13 Turbulence measurements vs. altitude, Test 9.

4.9.9 Summary of Test 9. Test 9 was conducted at the lower plant site assuming a stack height of 366 m. The plume was released from an altitude of 1645 m MSL (730 m AGL). Winds were very light from the north to east and the atmosphere sufficiently unstable for well-organized convection to occur. Upon release, the plume moved slowly up-valley with large amplitude looping bringing the plume to the ground in a large sector. Maximum ground level concentrations occurred 2 to 4 km southwest of the lower plant site where one-hour concentrations of about 400 to 900 μgm^{-3} were experienced. Aerial SF_6 samples showed one-minute concentrations as high as 5352 μgm^{-3} within 60 m of the surface in the area of maximum ground impact. Oil-fog tracking data show measurable concentrations from 1100 to 1700 m MSL. The normalized measured centerline concentration indicates rapid (B-C stability) dispersion. Turbulence dissipation rates were within the range expected for C stability.

In summary, this test showed that widespread dispersion of stack effluents, with one-hour surface concentrations as high as 902 μgm^{-3}, may be expected with a 366 m stack during periods of unstable conditions and low wind speeds.

4.10 Test Number Ten, August 7, 1976

Test 10 was conducted from the upper plant site during the morning of August 7, 1976. A stack height of 183 m was assumed and a plume rise of 335 m giving an effective stack height of 1890 m MSL. The light northwest winds and slightly stable conditions appeared favorable for further observation of plume behavior over the elevated terrain to the south and east. However, rapidly deteriorating visibility conditions, due to increasing low clouds, led a worried project director to discontinue tracer dissemination after about forty minutes. Aerial tracking and observation continued, but poor visibility hampered fixed-wing operations.

4.10.1 Synoptic Setting for Test 10. The project weather of August 7, 1976, was controlled by a 500-mb low centered during the morning in northern Oregon. A surface low pressure system was located in central Washington. This surface low pressure system and a high pressure system off the coast resulted in low-level northerly winds over the project area. Cloudiness consisted of broken stratocumulus with some cumulus underneath and considerable scud over the hills.

Surface and 700-mb maps are shown in Figure 4.10-1.

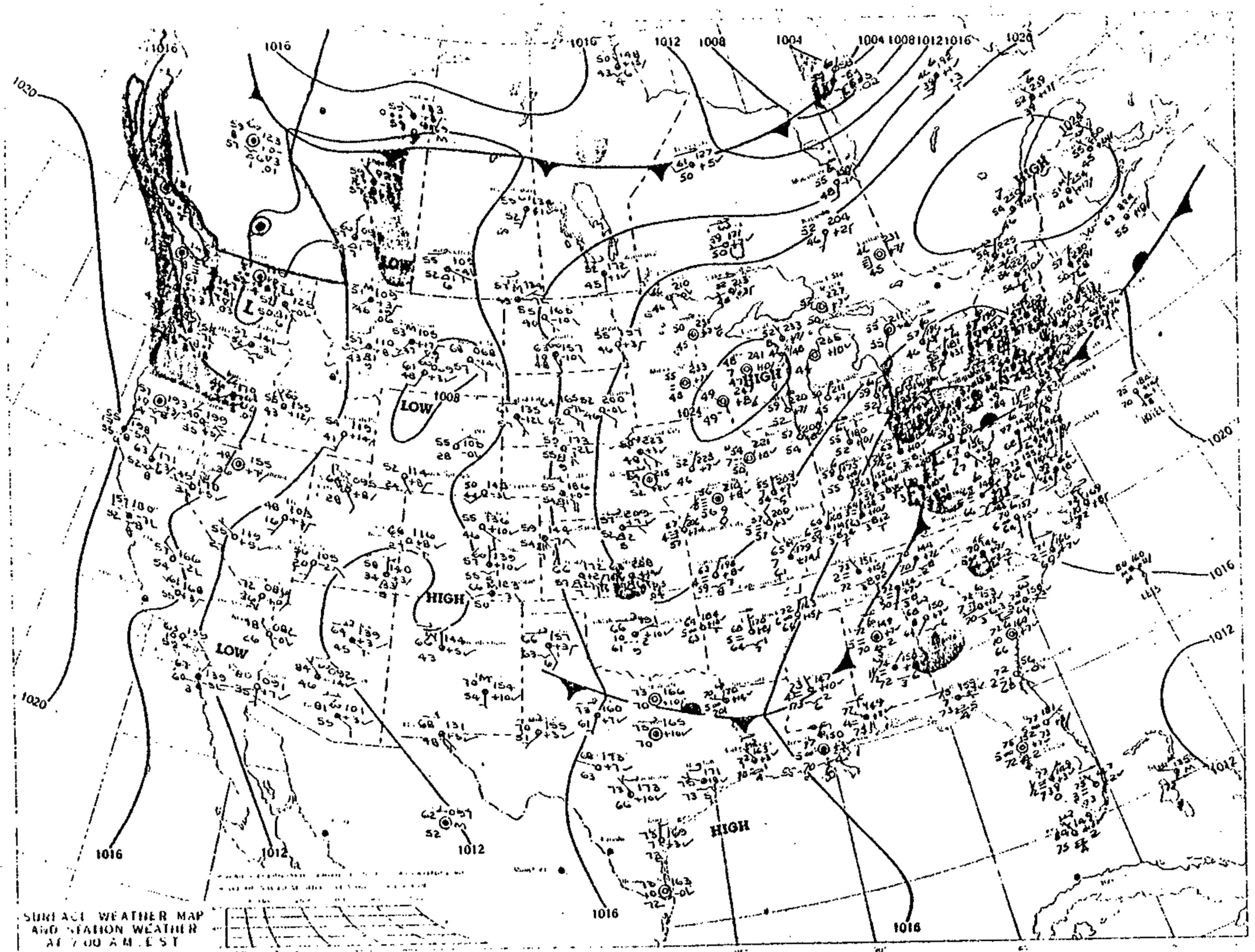


Figure 4.10-1 Surface and 500 mb charts, Test 10, August 7, 1976, 0400 PST.

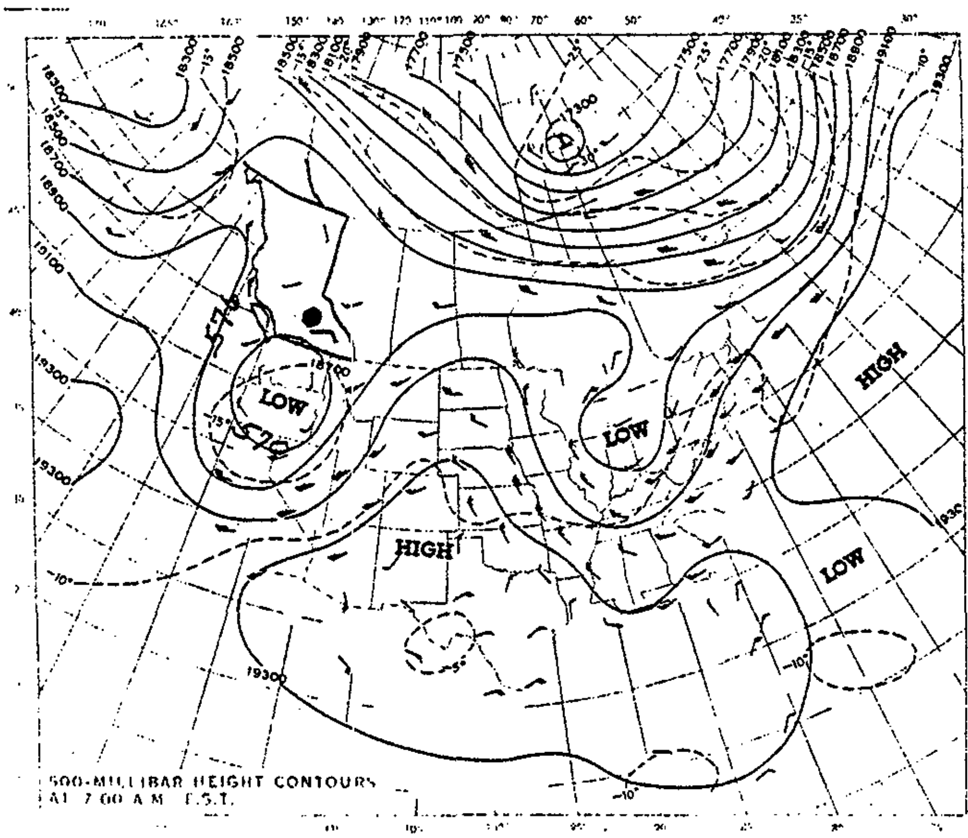


Figure 4.10-1 (Cont'd).

4.10.2 Meteorological Parameters for Test 10. Meteorological parameters measured during this test included temperature lapse rates, winds aloft, and surface winds. Temperature soundings were made by the NAWC tracer aircraft. Winds aloft data were gathered from double tracked pilot balloon ascents. Surface winds were measured by the B. C. Hydro field station network.

The temperature soundings from this test are presented in Figure 4.10-2. These show that near-neutral to slightly stable conditions prevailed at release altitude during the test. The early morning soundings show a surface-based isothermal layer 400 m thick at the lower site which extended to 100 m AGL at the

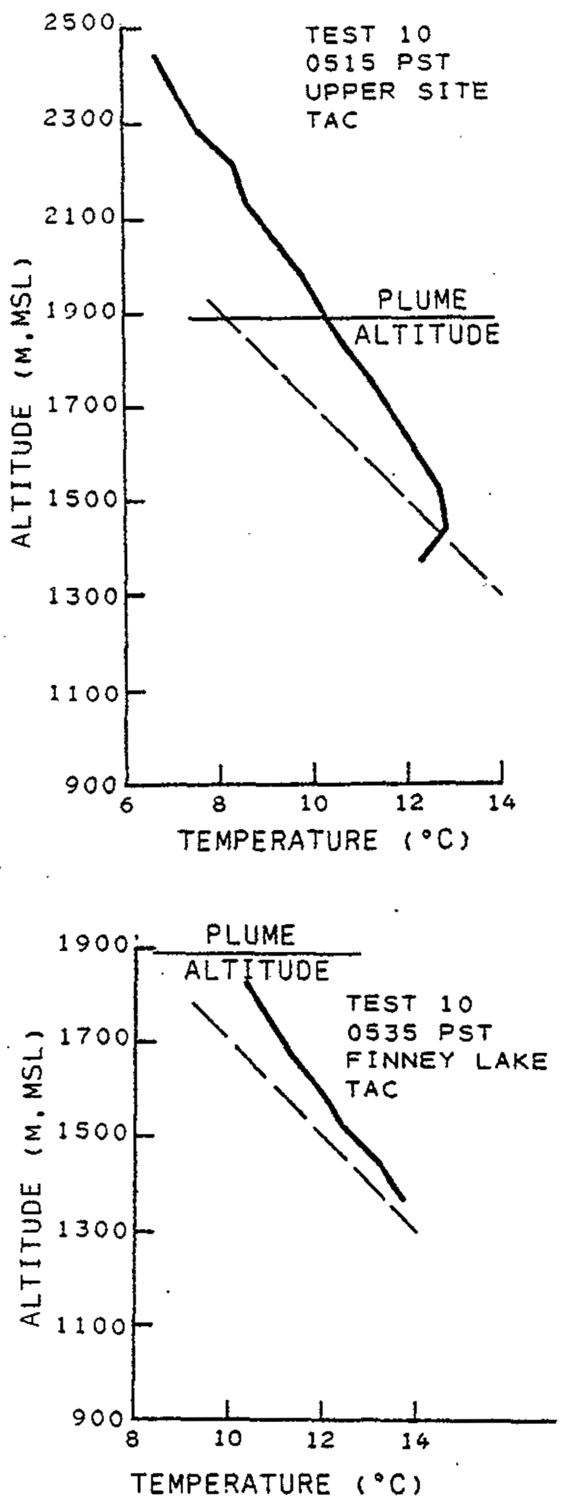


Figure 4.10-2 Vertical temperature profiles measured during Test 10.

upper site. No inversion was observed in an 0535 PST sounding at Finney Lake.

The surface wind data for Test 10 may be found in Volume 2, Field Data. These data indicate light down-valley flow at available sites during the test.

The winds aloft data are presented as wind direction and wind speed time sections in Figures 4.10-3 and 4.10-4. These show north to northwest winds of 1-2 m/s prevailed during the test at release height. Winds nearer the surface were northeasterly at about 2 m/s.

4.10.3 Tracer Dissemination, Test 10. Pertinent tracer dissemination parameters for Test 10 are given in Table 4.10-1, below.

Table 4.10-1 Duration and source strength of tracer release number 10.

Location: Upper Plant Site
Altitude: 1890 m MSL
Simulated Stack Height: 183 m
Stability Classification: D-E

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0539	0618	13,166	5.56
Oil Fog	0539	0618	109,800	46.3

4.10.4 Visual and Photographic Observations. Plume transport was toward the south-southeast at an average speed of 2.5 m/s throughout the test. Figure 4.10-5 shows the coning plume 11 minutes after the release began. Scud based at about 1500 m MSL obscured the hills east of the plume and eventually enveloped the plume by 0640 PST or 61 minutes after the release began.

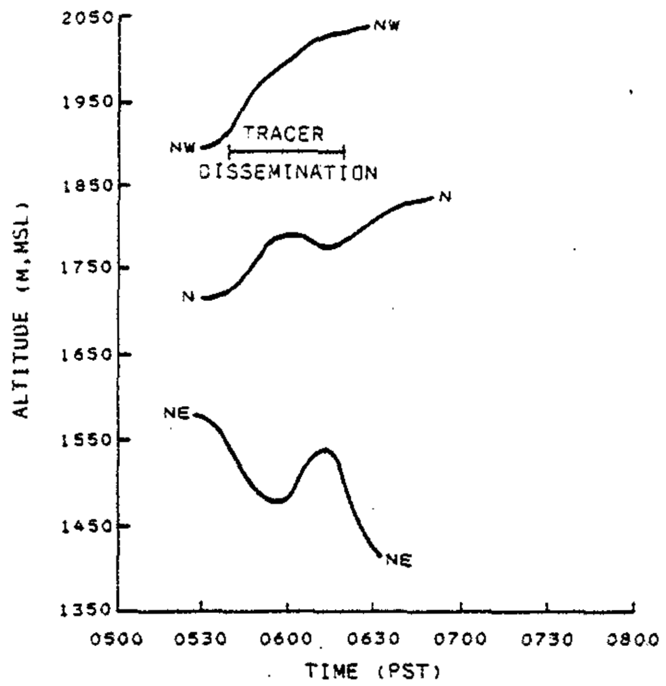


Figure 4.10-3 Time vs. altitude display of wind directions aloft measured during Test 10. Speeds are given in m/s.

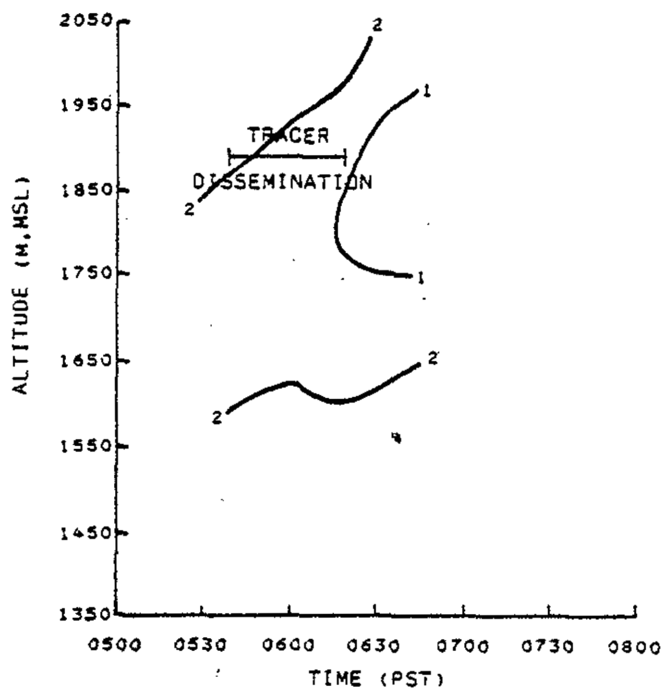


Figure 4.10-4 Time vs. altitude display of wind speeds aloft measured during Test 10. Speeds are given in m/s.

Figure 4.10-5 Photo, Test 10. This photo, taken at 0541 PST, shows the coning plume moving south from the release point at the upper site. The stratus layer in the background moved over the area about 30 minutes after this was taken forcing curtailment of the test. View is towards the east.

Rain began falling during this period and further observation was cancelled.

Plume outlines for two times when the position could be determined are shown in Figure 4.10-6.

4.10.5 Aerial Oil-Fog Measurements. The aerial oil-fog measurements for Test 10 consist of one set of crosswind passes flown over Medicine Creek, 2.9 km downwind of the proposed upper plant site, as shown in Figure 4.10-7. The passes were conducted between 0615 and 0630 PST. The maximum concentration, equivalent to 23,805 μgm^{-3} was found at an altitude of 1860 m MSL. The plume layer extended between 2000 and 1700 m MSL and was about 2 km wide at the centerline. The vertical and horizontal distribution of the plume at the centerline can be seen in Figure 4.10-8. The values of σ_y, σ_z and $\frac{X\bar{u}}{Q}$ for these measurements have been calculated

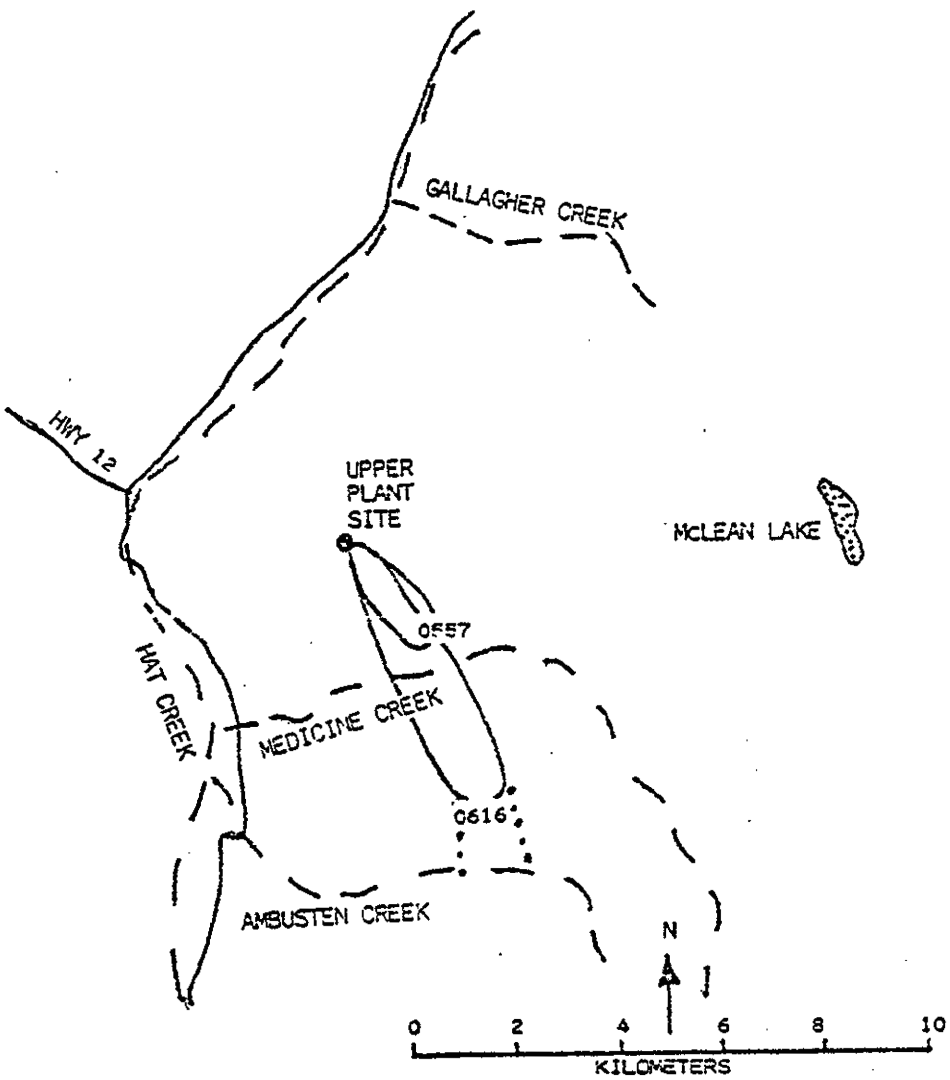


Figure 4.10-6 Plume outlines at various times during Test 10.

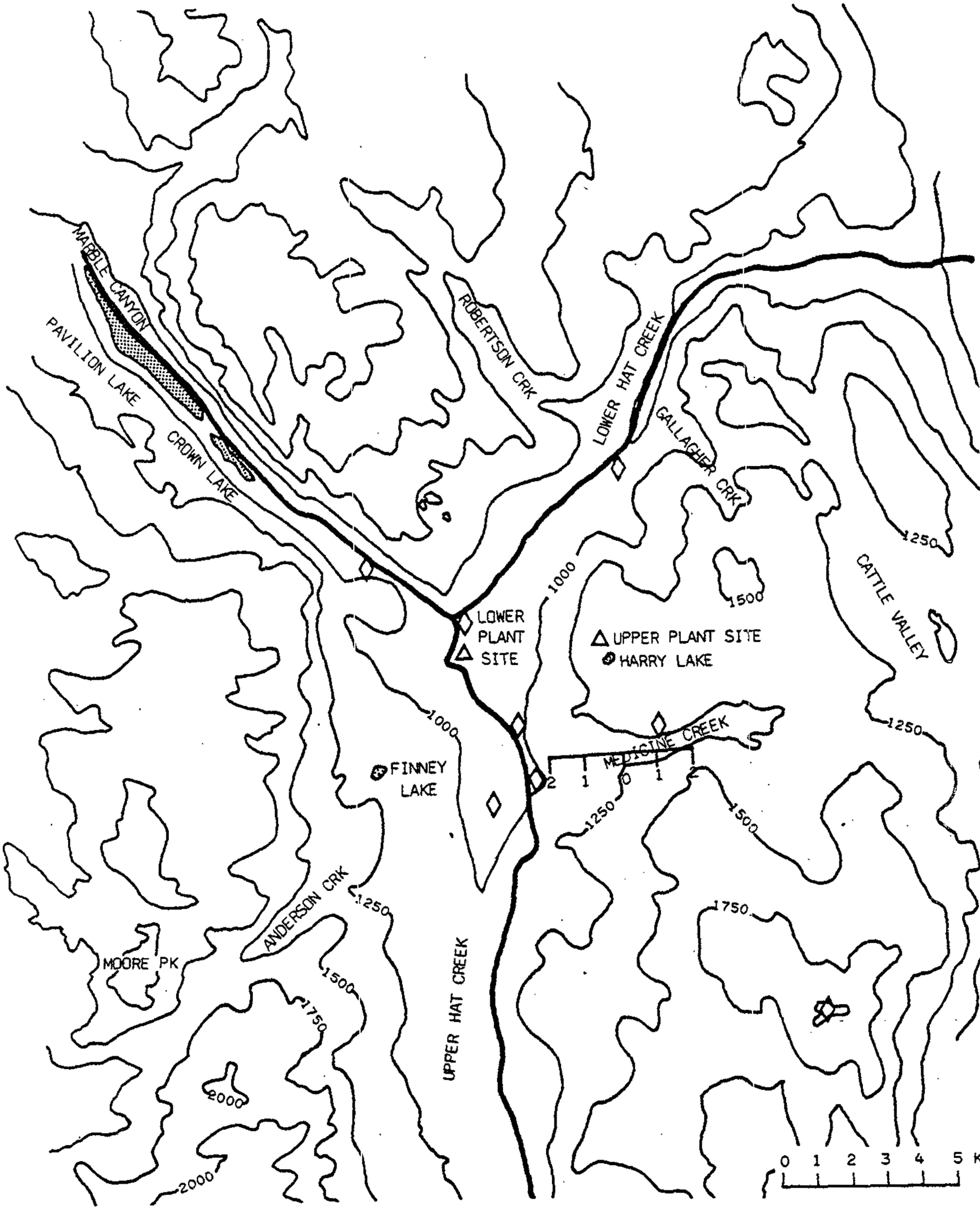


Figure 4.10-7 Location of aerial oil-fog crosswind patterns, Test 10. Distances are in kilometers.

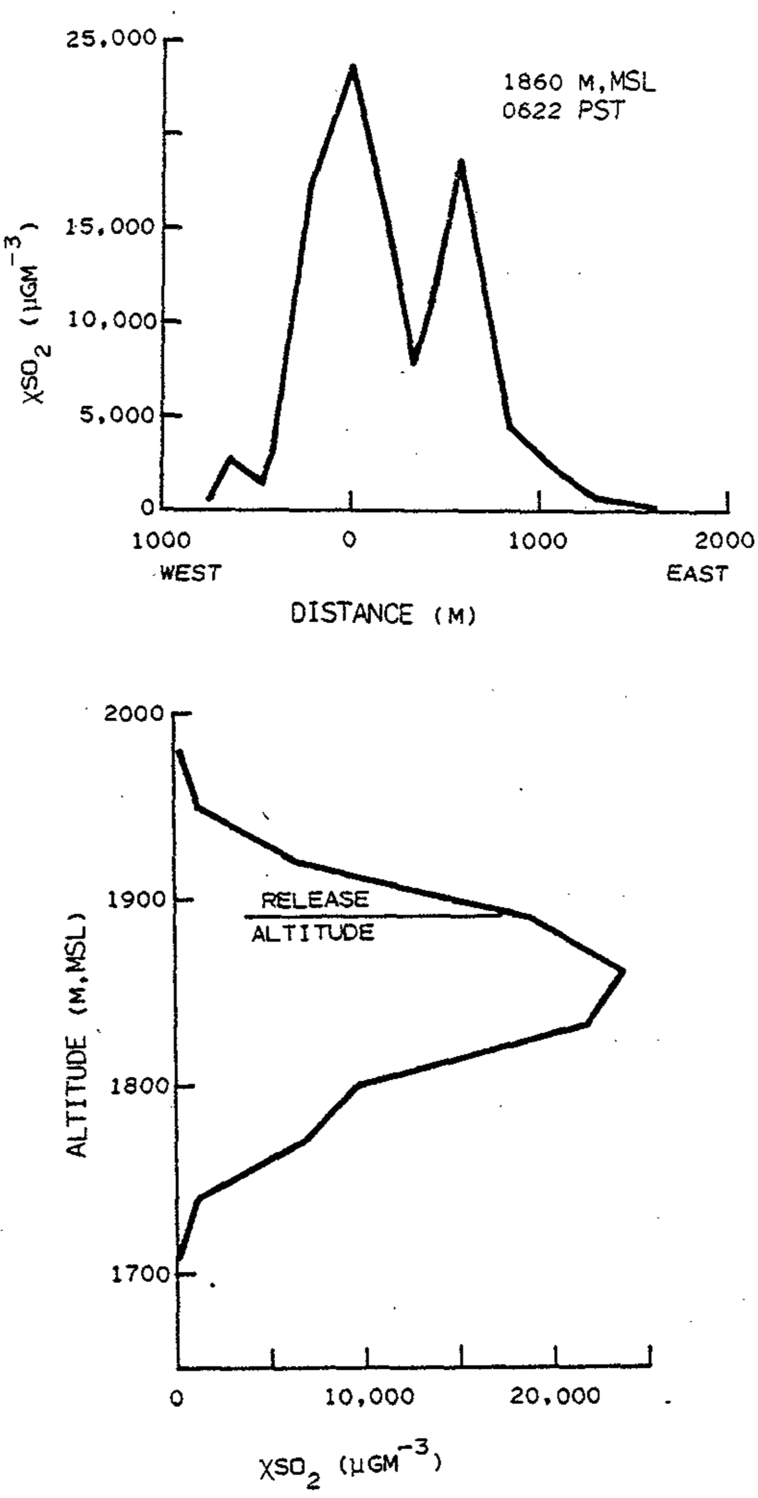


Figure 4.10-8 Horizontal and vertical plume centerline distributions, Test 10.

and appear in Figures 4.10-9 and 4.10-10, respectively. The dispersion coefficients indicate stable plume geometry, while the normalized concentration suggests a centerline dilution rate nominal for a neutral atmosphere.

4.10.6 Aerial SF_6 Measurements. Due to meteorological conditions unsuitable for sustained, low-level flight, no aerial SF_6 data is available from this test.

4.10.7 Surface SF_6 Measurements. Ten SF_6 samplers were deployed southeast of the upper plant site as shown in Figure 4.10-11. Supplementary sampler data is given in Table 4.10-2. No SF_6 was detected at any of these sampler sites. The samplers placed in Medicine Creek Valley were below the inversion; thus, none would be expected at those sites. However, sampler 10S3 was only 180 m below the release height and the plume appeared to pass directly over it. The fact that no SF_6 was found here suggests that vertical dispersion was proceeding more slowly than might be expected.

4.10.8 Turbulence Measurements. The turbulence measurements available for Test 10 are from the oil-fog crosswind passes (see map, Figure 4.10-7) and are displayed in Figure 4.10-12. It can be seen that turbulence was rather light and showed little change with altitude. The values observed indicate a D-E dispersion environment. The intermittence values suggest a fairly uniform regime and also showed little trend with altitude. The low rates of turbulence dissipation were apparently related to the low wind speeds and low-level stability.

4.10.9 Summary of Test 10. The Test 10 tracer plume was released from an altitude of 1890 m MSL at the upper plant site using an assumed stack height of 183 m MSL. Due to poor visibility in the project area, the tracer release was terminated

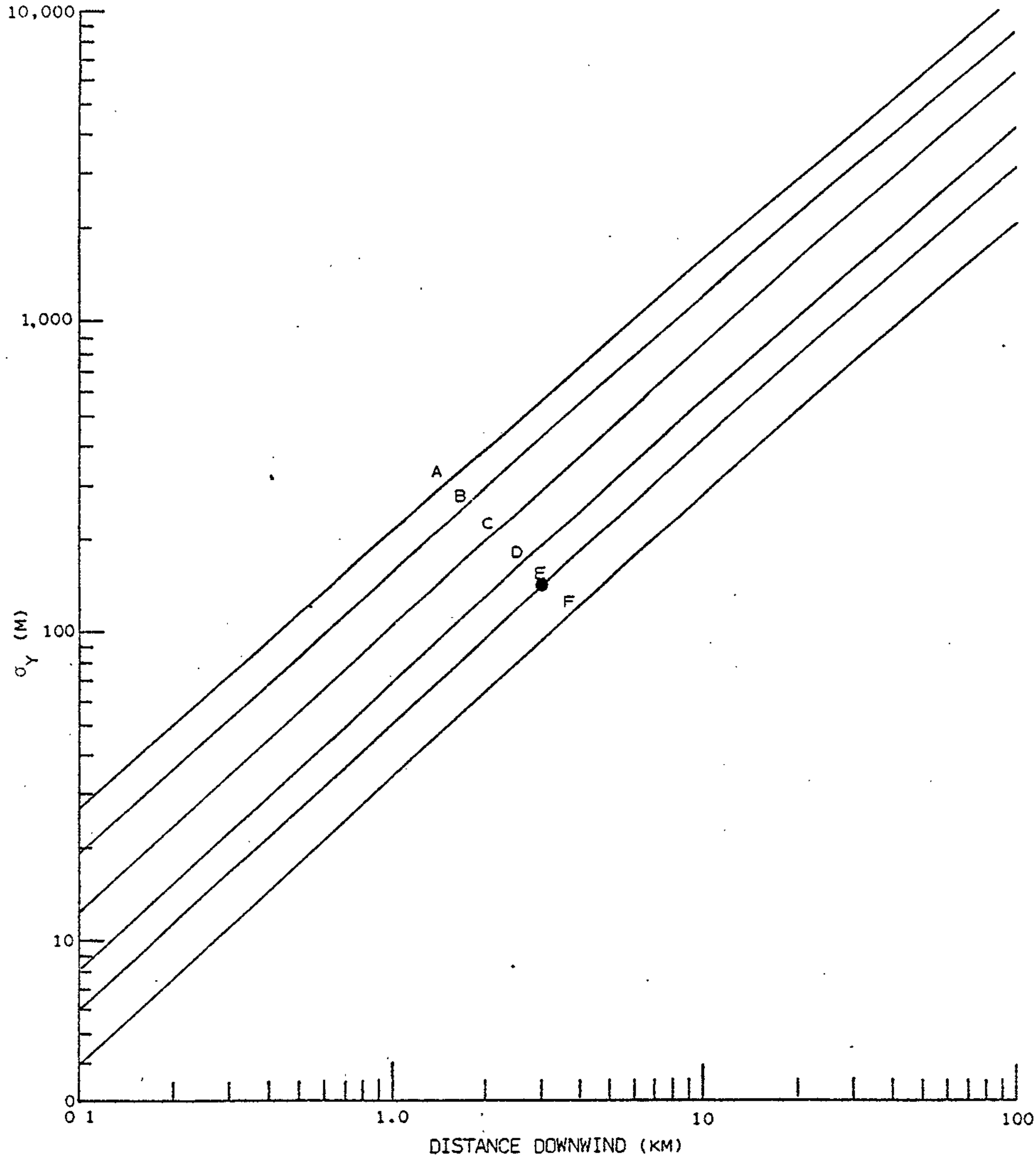


Figure 4.10-9 Measured values of σ_y and σ_z for Test 10.

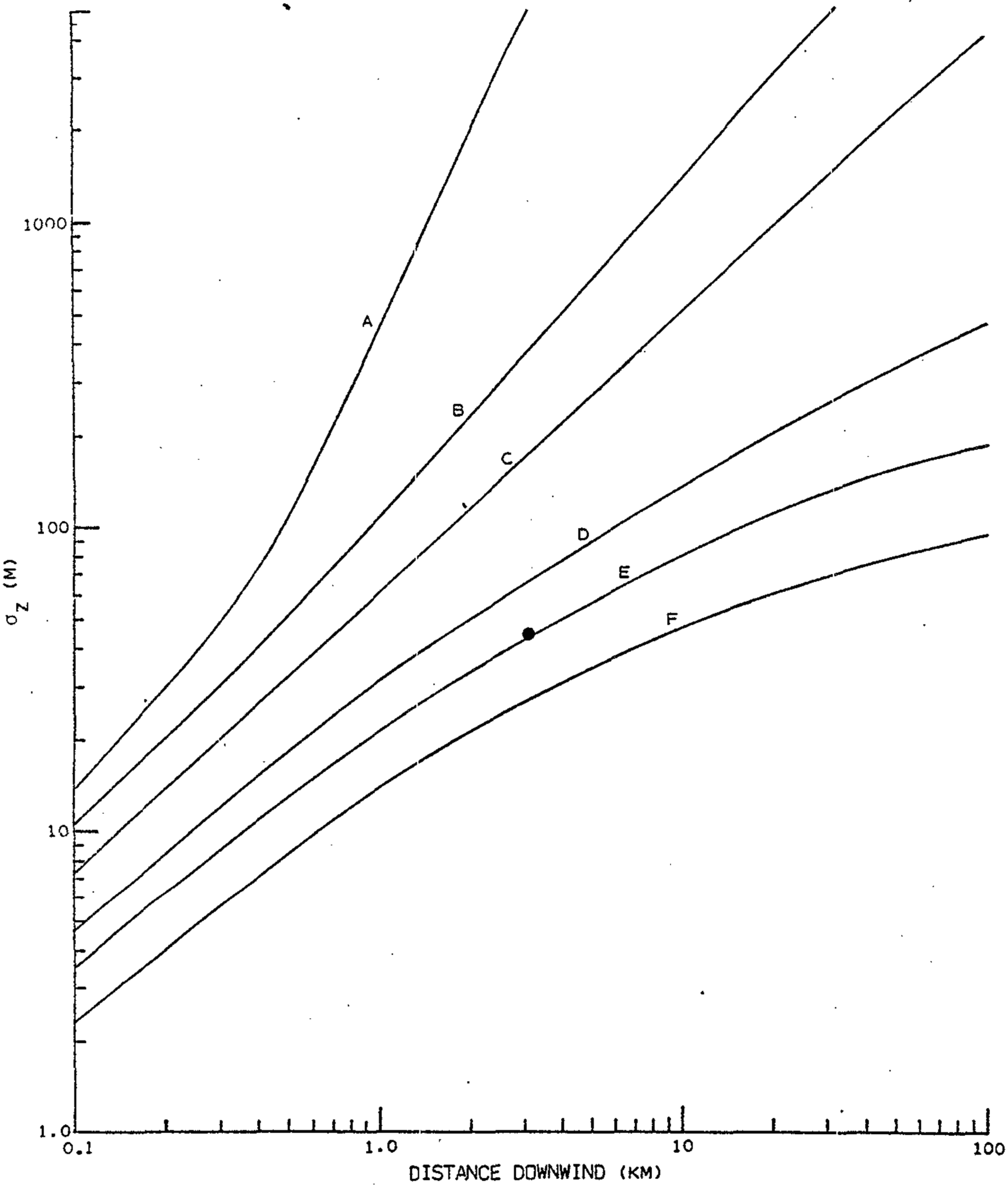


Figure 4.10-9 (Cont'd).

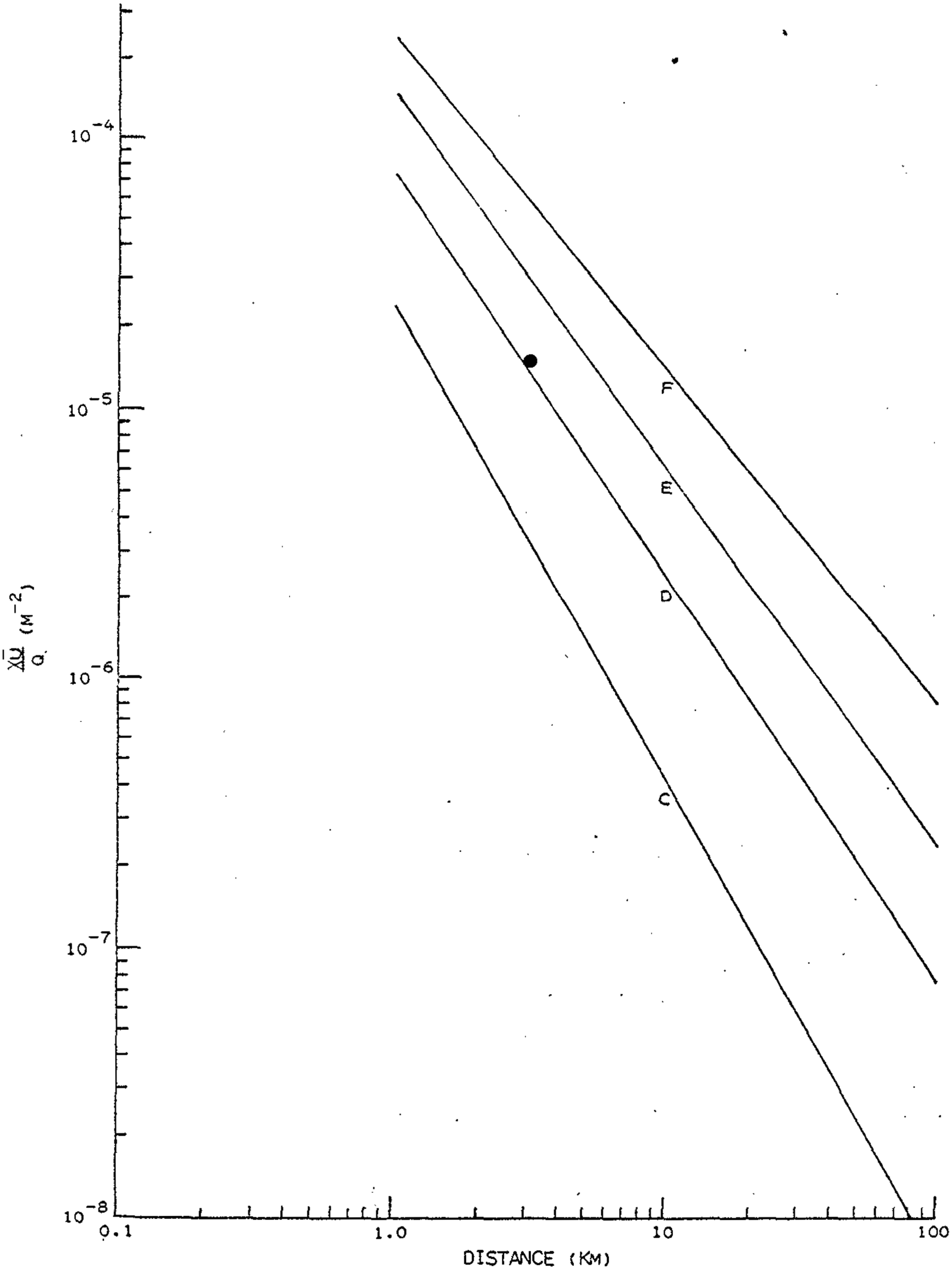


Figure 4.10-10 Measured values of $\frac{\chi \bar{u}}{Q}$ for Test 10.

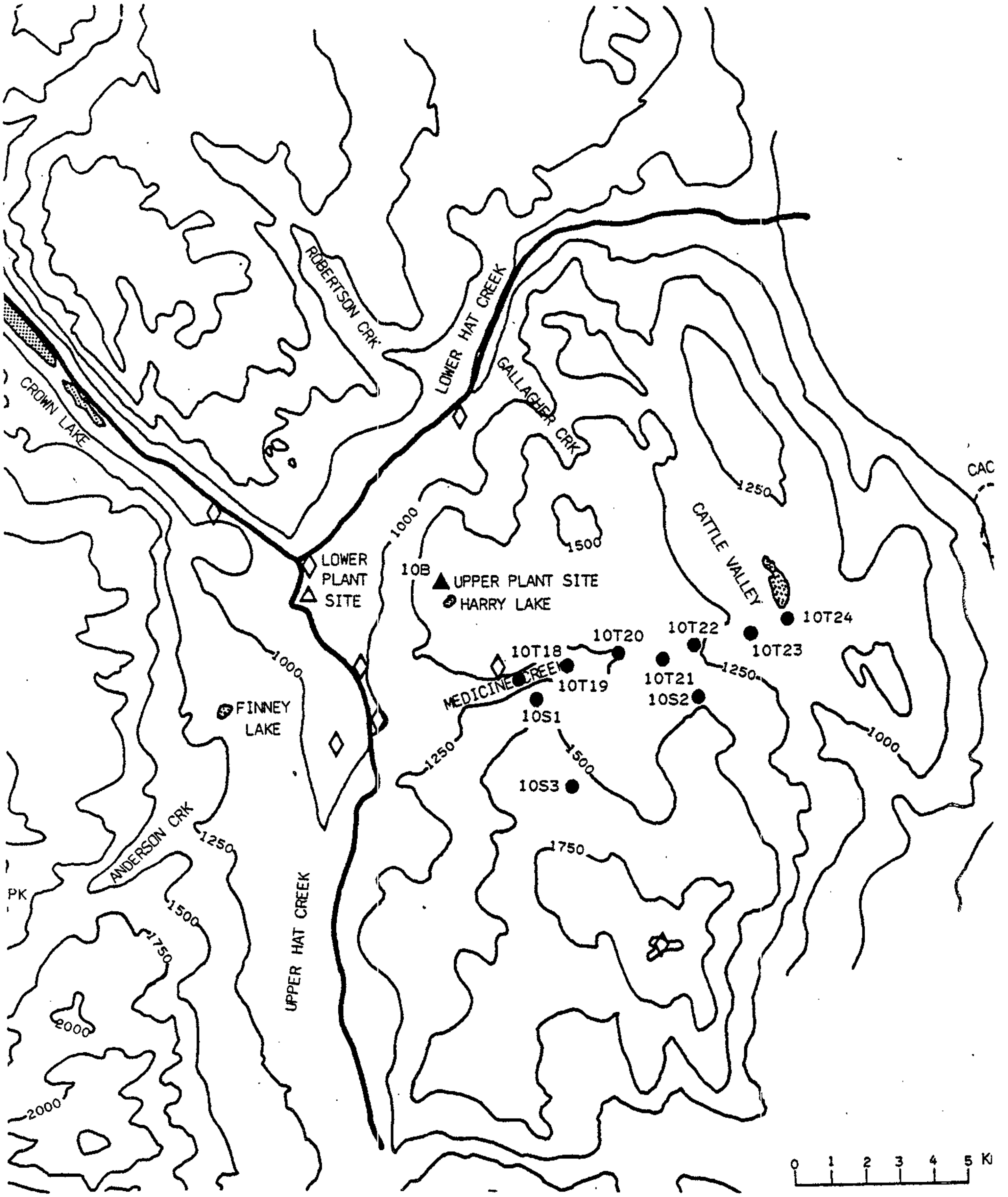
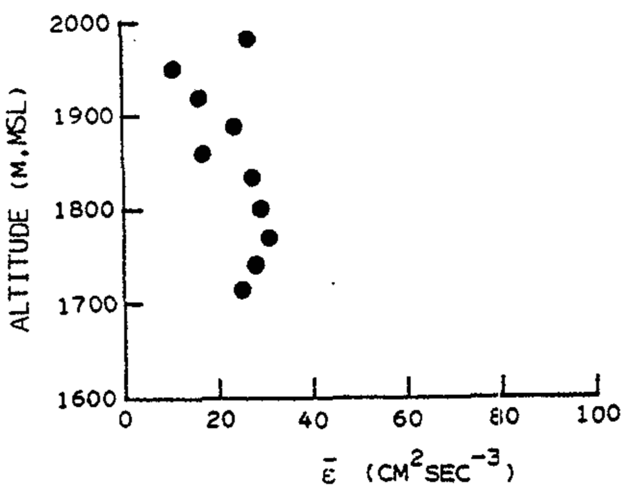


Figure 4.10-11 Location of surface SF_6 samplers, Test 10.

Table 4.10-2 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
10S1	4.3	1450	0558	0628	30	Malf.	-
			0628	0658	30	0	0
			0658	0728	30	0	0
10S2	8.2	1465	0608	0638	30	Malf.	-
			0638	0708	30	0	0
			0708	0737	29	0	0
10S3	7.2	1710	0615	0645	30	Malf.	-
			0645	0715	30	0	0
			0715	0745	30	0	0
			0745	0815	30	0	0
			0815	0845	30	0	0
			0845	0915	30	Malf.	-
10T18	3.2	1310	0530	0635	65	0	0
10T19	4.3	1220	0536	0628	52	0	0
			0628	0640	12	Malf.	-
10T20	5.4	1250	0540	0623	43	0	0
			0623	0645	22	0	0
10T21	6.8	1310	0620	0650	30	0	0
10T22	7.8	1310	0552	0615	17	0	0
			0615	0651	36	0	0
10T23	9.0	1160	0608	0656	48	0	0
10T24	10.5	1085	0600	0700	60	0	0
10B	0.0	1370	0500	0600	60	0	0
			0600	0645	45	0	0



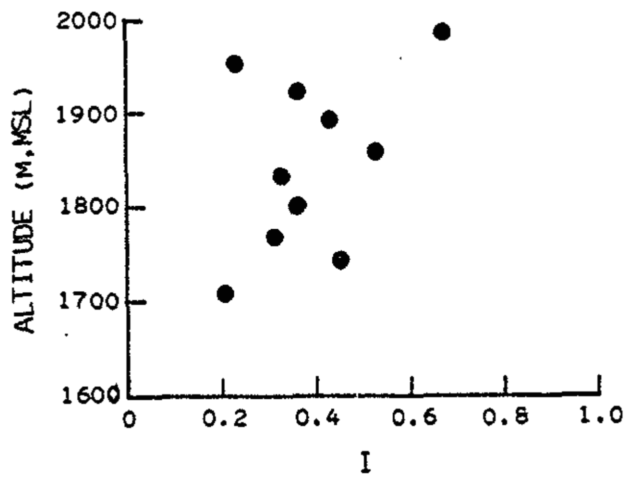


Figure 4.10-12 Turbulence measurements vs. altitude, Test 10.

after forty minutes. The plume altitude winds were from the northwest at 1 to 2 m/s. Lapse rates were somewhat stable, about -0.5°C per 100 m. No SF_6 was detected by the surface network though the plume passed directly over at least one sampler, suggesting slow downward mixing. Aerial oil-fog data confirm somewhat stable plume geometry, though the normalized centerline concentration indicates neutral stability dilution rates. The aerial data show rates of turbulence dissipation nominal for D-E stability.

It is concluded that the low wind speeds, slight stability and cloudiness combined to suppress mechanical and thermal turbulence, resulting in little vertical mixing and below-threshold surface concentrations.

4.11 Test Number Eleven, August 9, 1976

Test 11 was carried out from the upper plant site during the morning of August 9, 1976. A stack height of 183 m was assumed, with plume rise of 366 m, giving an effective source height of 1920 m

MSL. The meteorological conditions dictated investigation of plume dispersion over the terrain to the southeast under neutral, windy conditions.

4.11.1 Synoptic Setting for Test 11. The area of low pressure that had influenced project weather during the preceding several days moved east of the project area and into the Rocky Mountains during August 8, 1976. As a result, high pressure, both at the surface and aloft, dominated the weather on August 9, 1976. The low-level gradient flow was northwesterly over the project area. Cloudiness consisted of broken stratocumulus with some scud over the hills.

Surface and 700-mb maps are shown in Figure 4.11-1.

4.11.2 Meteorological Parameters for Test 11. Measurements were made of temperature lapse rates, surface winds, and winds aloft during this test. Temperature soundings were made by the NAWC tracer aircraft and by tethered sonde. Surface wind data were gathered by the B. C. Hydro meteorological station network. Double tracked pilot balloon ascentions provided data on winds aloft.

The temperature soundings available for Test 11 are presented in Figure 4.11-2. It can be seen that near neutral conditions prevailed at plume release altitude during the test. Soundings taken at about 0800 PST at Ashcroft Airstrip and at the upper plant site reveal surface based super adiabatic layers about 100 m thick.

The surface wind data for this release may be found in Volume II, Field Data. These data reflect the relatively strong gradient winds and show northerly flow at sites in the upper valley throughout test at speeds ranging from 2-5 m/s.

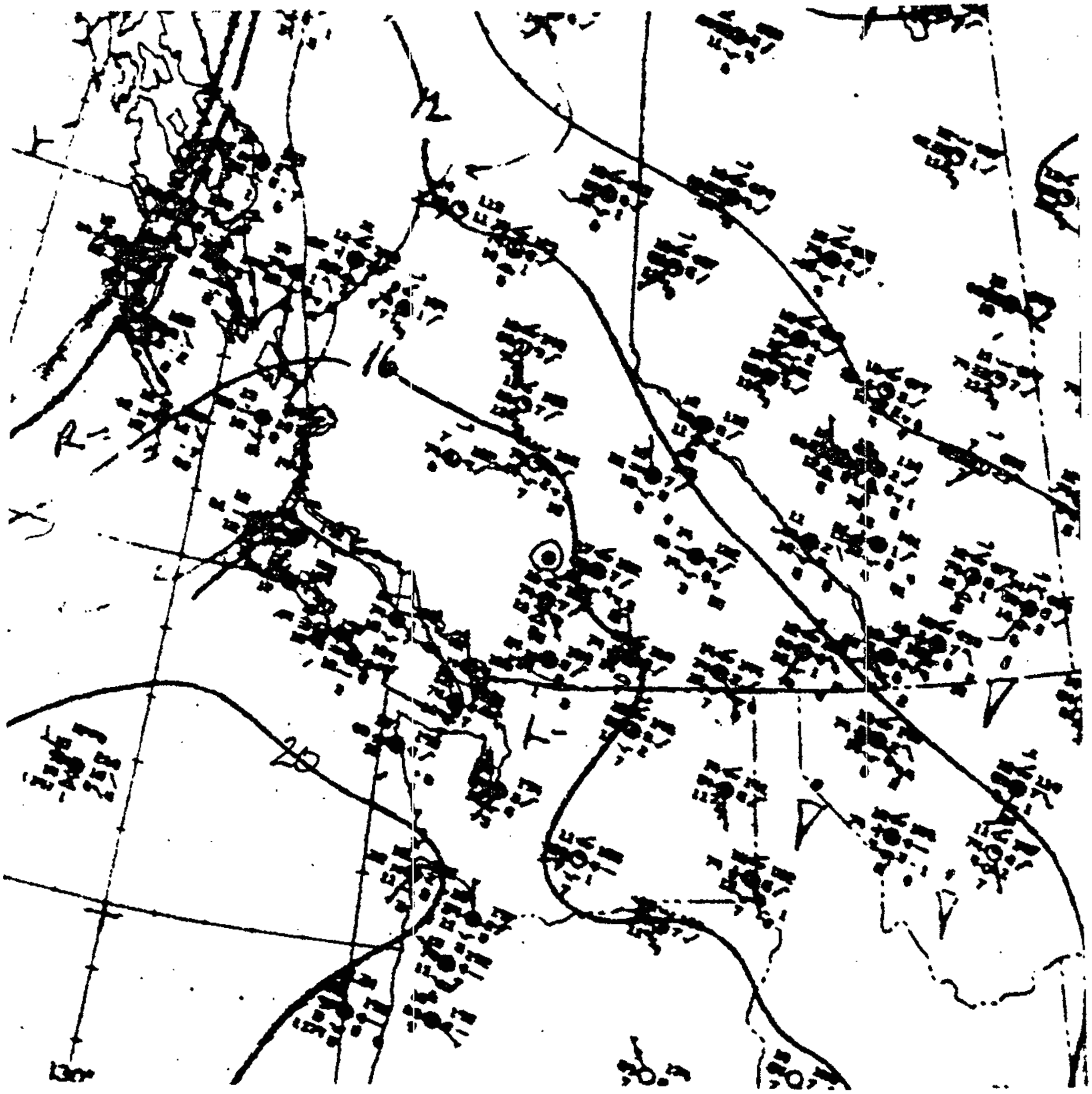


Figure 4.11-1 Surface and 500 mb charts, Test 11, August 9, 1976, 0400 PST.

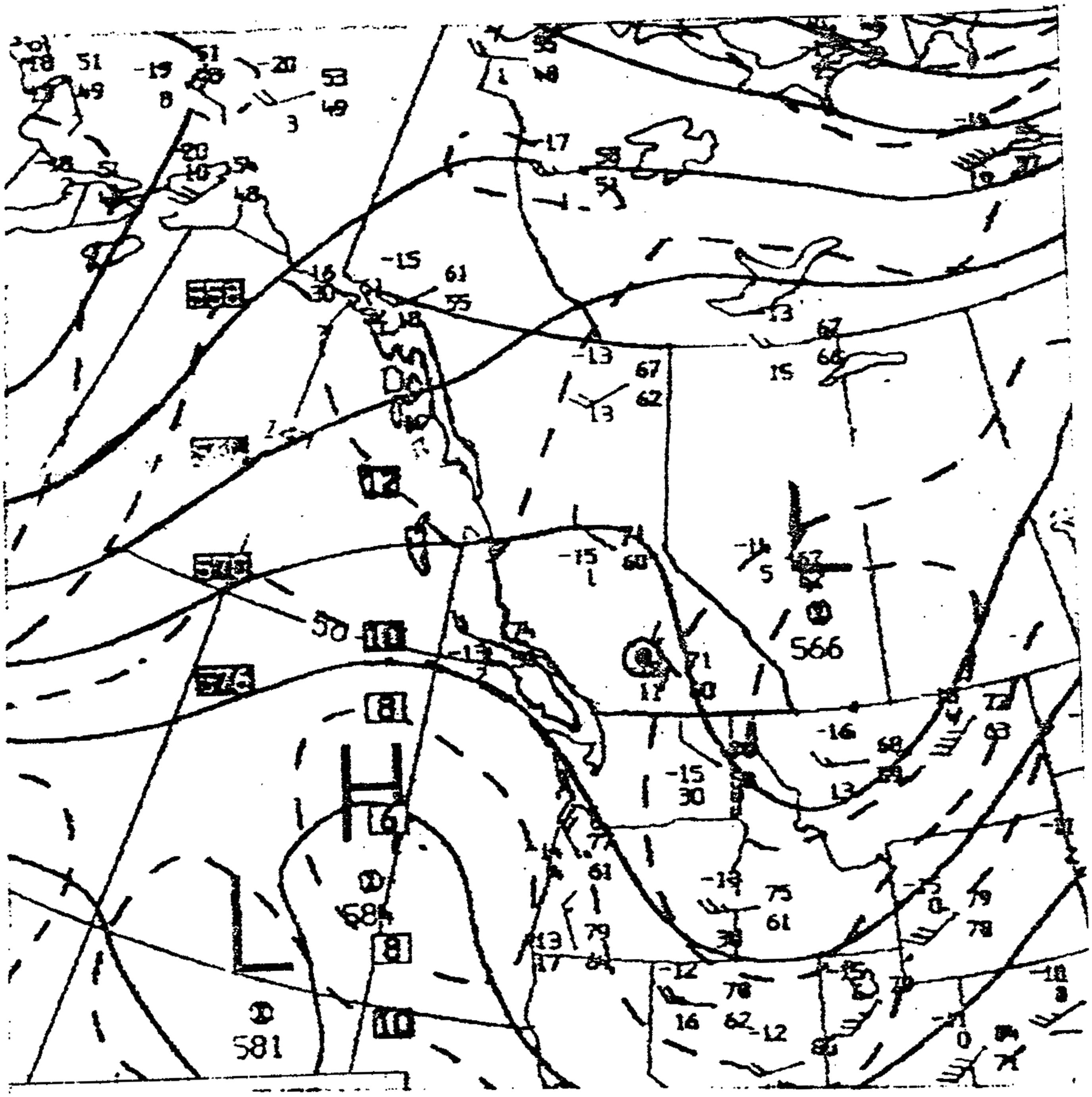


Figure 4.11-1 (Cont'd)

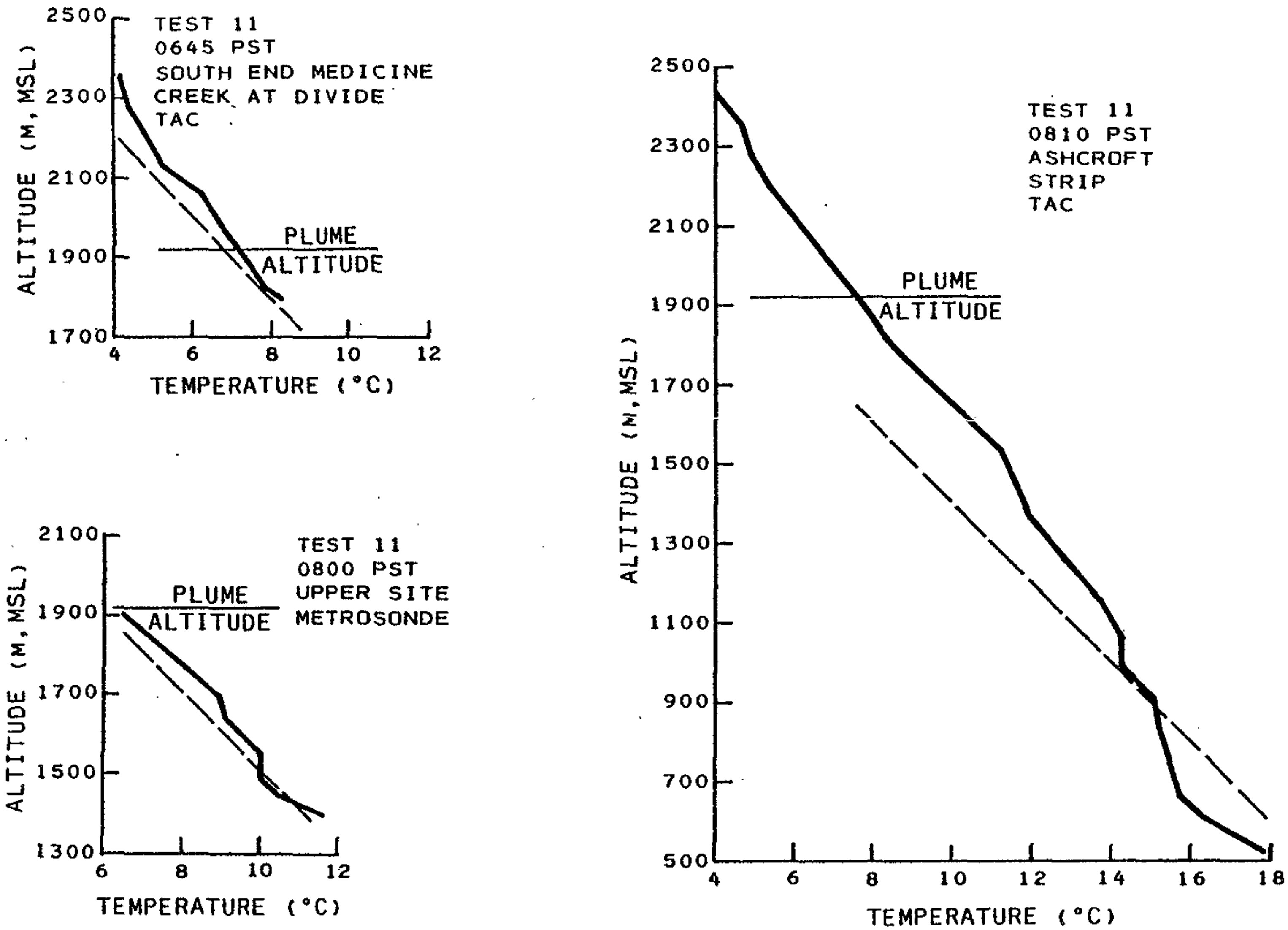


Figure 4.11-2 Vertical temperature profiles measured during Test 11.

The winds aloft time sections of wind direction and wind speed are shown in Figures 4.11-3 and 4.11-4, respectively. Throughout the test, winds at release altitude were from the northwest at speeds of 7-8 m/s. Winds nearer the surface were more westerly at 4-7 m/s. Little development of the valley circulation is evident.

4.11.3 <u>Tracer Dissemination, Test 11</u>. Pertinent tracer release parameters for this test are contained in Table 4.11-1, below.

Table 4.11-1 Duration and source strength of tracer release number 11.

Location: Upper Site
Altitude: 1920 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0647	0747	21,540	5.98
Oil Fog (1)	0647	0723	109,800	50.8
Oil Fog (2)	0737	0747	N/A	N/A

4.11.4 <u>Visual and Photographic Observations</u>. Transport of the coning oil-fog plume was toward the southeast at an average speed of 8.9 m/s. Figure 4.11-5, looking obliquely downwind at 0714 PST, shows the rapidly dispersing plume passing over Medicine Creek.

Plume outlines at 0658 and 0711 PST are shown in Figure 4.11-6. The rapid dispersion prevented accurately locating the plume's leading edge after 0711 PST.

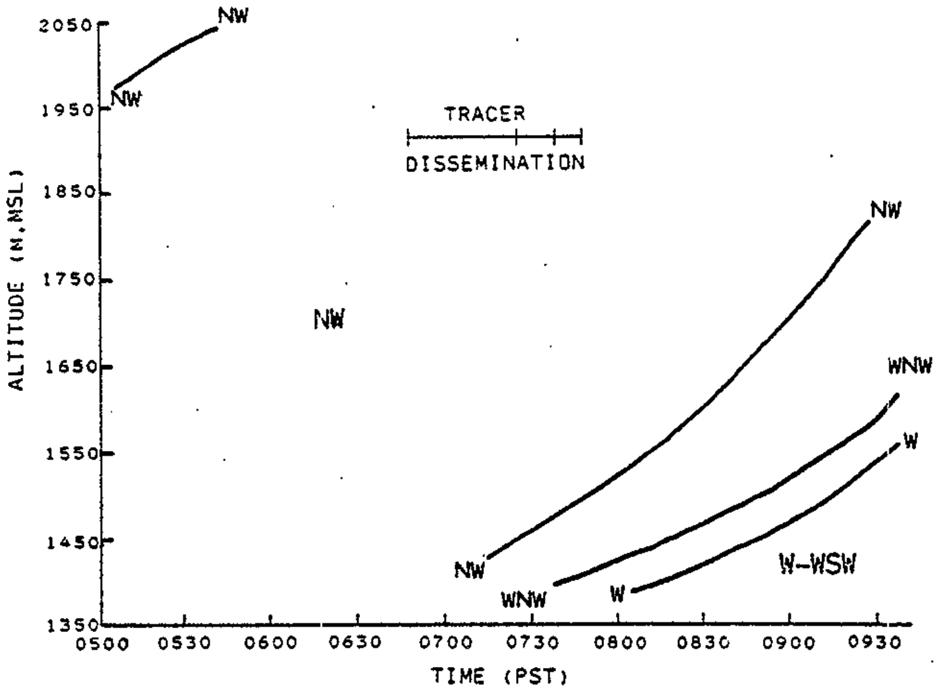


Figure 4.11-3 Time vs. altitude display of wind directions aloft measured during Test 11. Speeds are given in m/s.

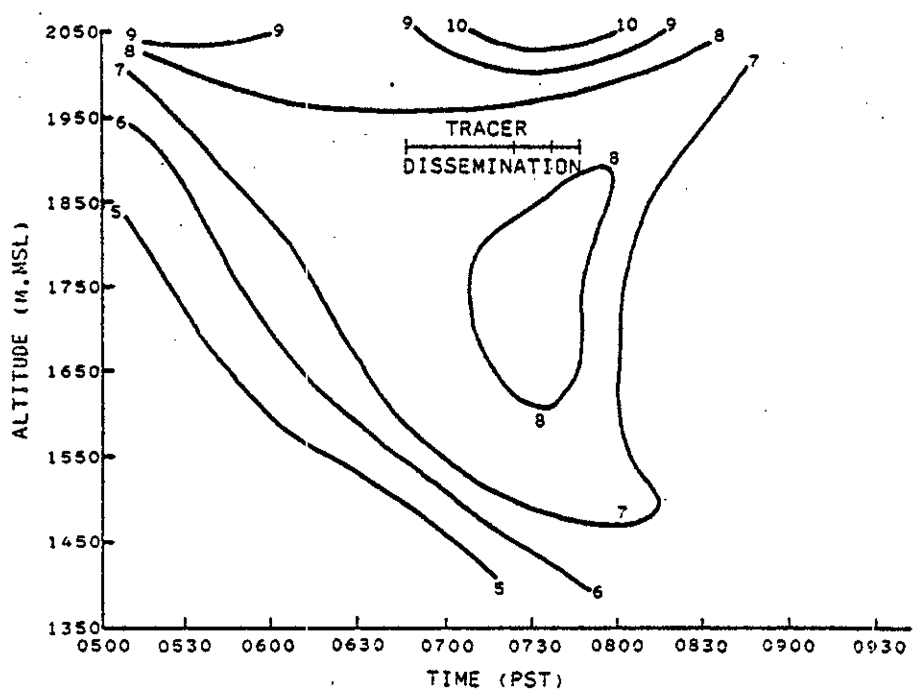


Figure 4.11-4 Time vs. altitude display of wind speeds aloft measured during Test 11. Speeds are given in m/s.

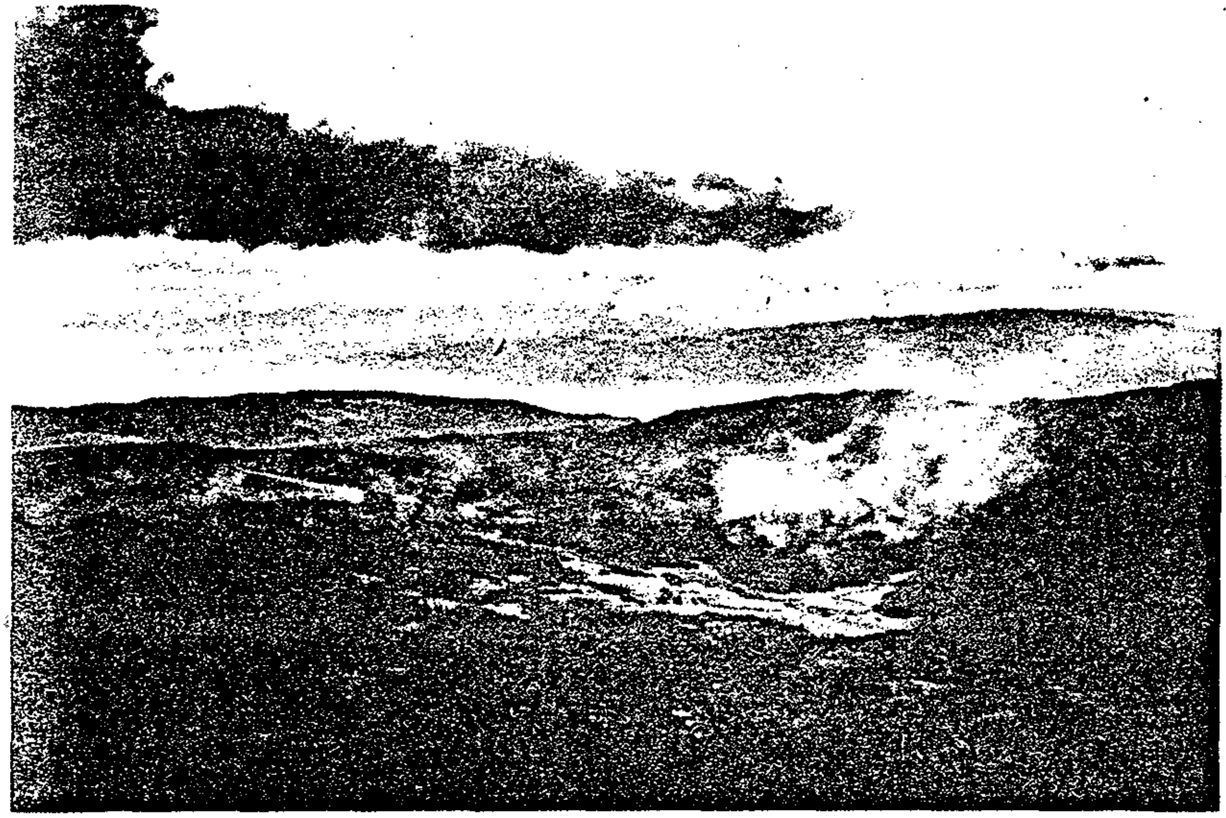


Figure 4.11-5 Photo, Test 11. This view towards the southeast shows the rapidly dispersing plume passing over Medicine Creek at 0714 PST.

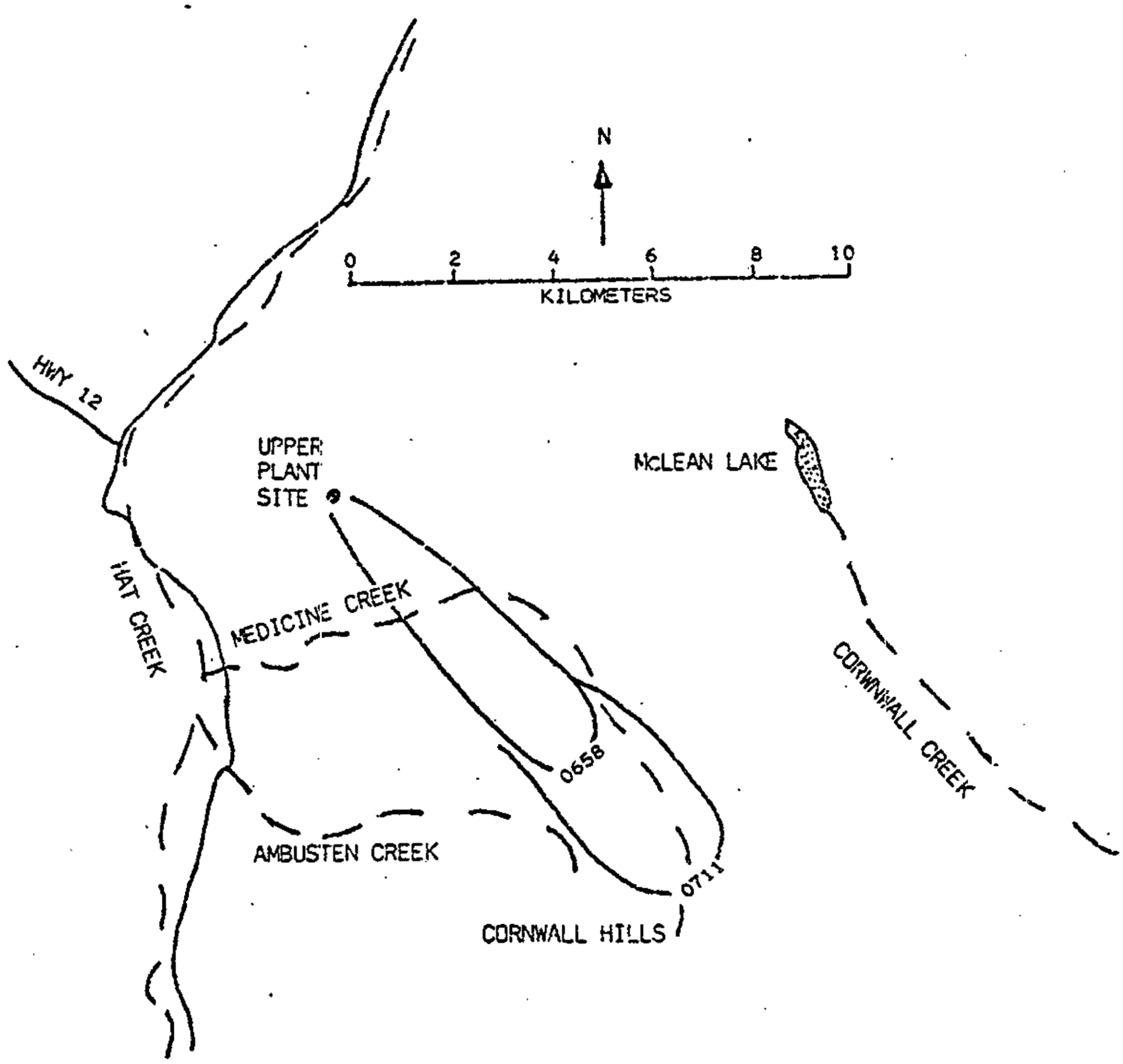


Figure 4.11-6 Plume outlines at various times during Test 11.

4.11.5 Aerial Oil-Fog Measurements. Three sets of oil-fog crosswind patterns were flown during Test 11. The locations are shown in Figure 4.11-7.

The first set of passes was made 4.2 km downwind, over upper Medicine Creek, from 0658 and 0721 PST. Sixteen individual crosswind passes were made at altitudes between 2015 and 1555 m MSL. The maximum concentration, equivalent to 4763 μgm^{-3}, was found at 1710 m MSL. The plot of horizontal and vertical plume distribution at the centerline is given in Figure 4.11-8. The centerline altitude indicates a rapid sinking of about 200 m from the release altitude. This feature may reflect downwash into Medicine Creek. The thickness of the plume indicates strong vertical mixing, while its width, about 1 km, suggests little meander in the flow at this time. The values of σ_y, σ_z, and $\frac{X\bar{u}}{Q}$ are plotted in Figures 4.11-9 and 4.11-10. The measurements of σ_y and σ_z suggest stable type plume geometry in the horizontal and near neutral geometry in the vertical. The normalized concentration indicates a centerline dilution rate nominal for a neutral atmosphere.

The second set of crosswind passes were flown over the steep slopes northeast of the Cornwall Hills about 14 km downwind of the release. These measurements were made between 0730 and 0745 PST. Here, the maximum concentration was found to be 2565 μgm^{-3} at altitudes of 1645 and 1525 m MSL. These altitudes indicate a further lowering of the plume layer. The plume distributions in the vertical and horizontal at the centerline are given in Figure 4.11-11. It can be seen that although the altitudes are lower, the depth of the plume layer appears to have changed little from that measured during the first set of passes. The width of the plume is about twice that found over Medicine Creek. The values of σ_y and σ_z, plotted in Figure 4.11-9, indicate little change in σ_y and an apparent decrease in σ_z when compared with the values from Set 1. A centerline dilution rate associated with

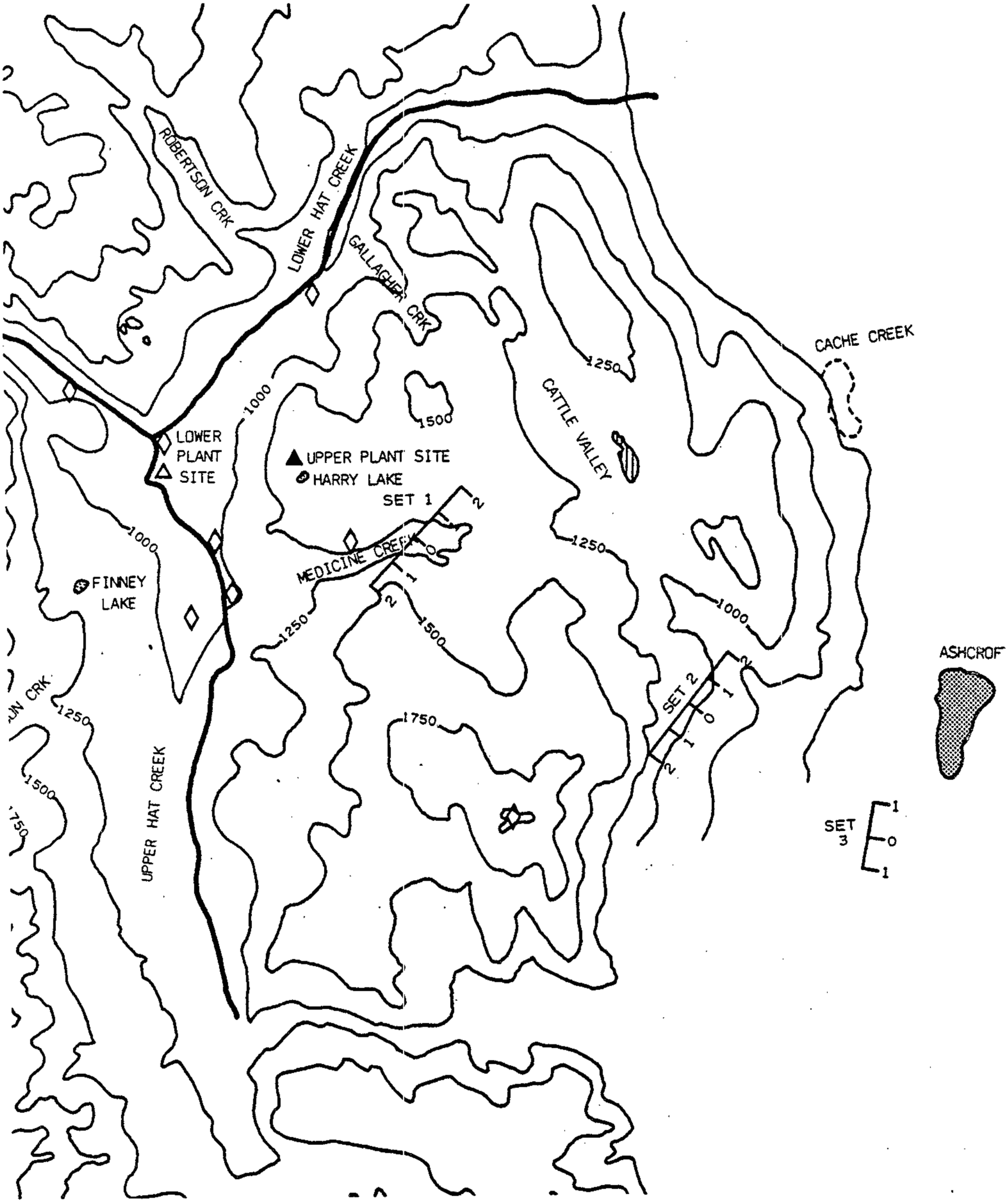


Figure 4.11-7 Locations of oil-fog crosswind patterns, Test 11. Distances are in kilometers.

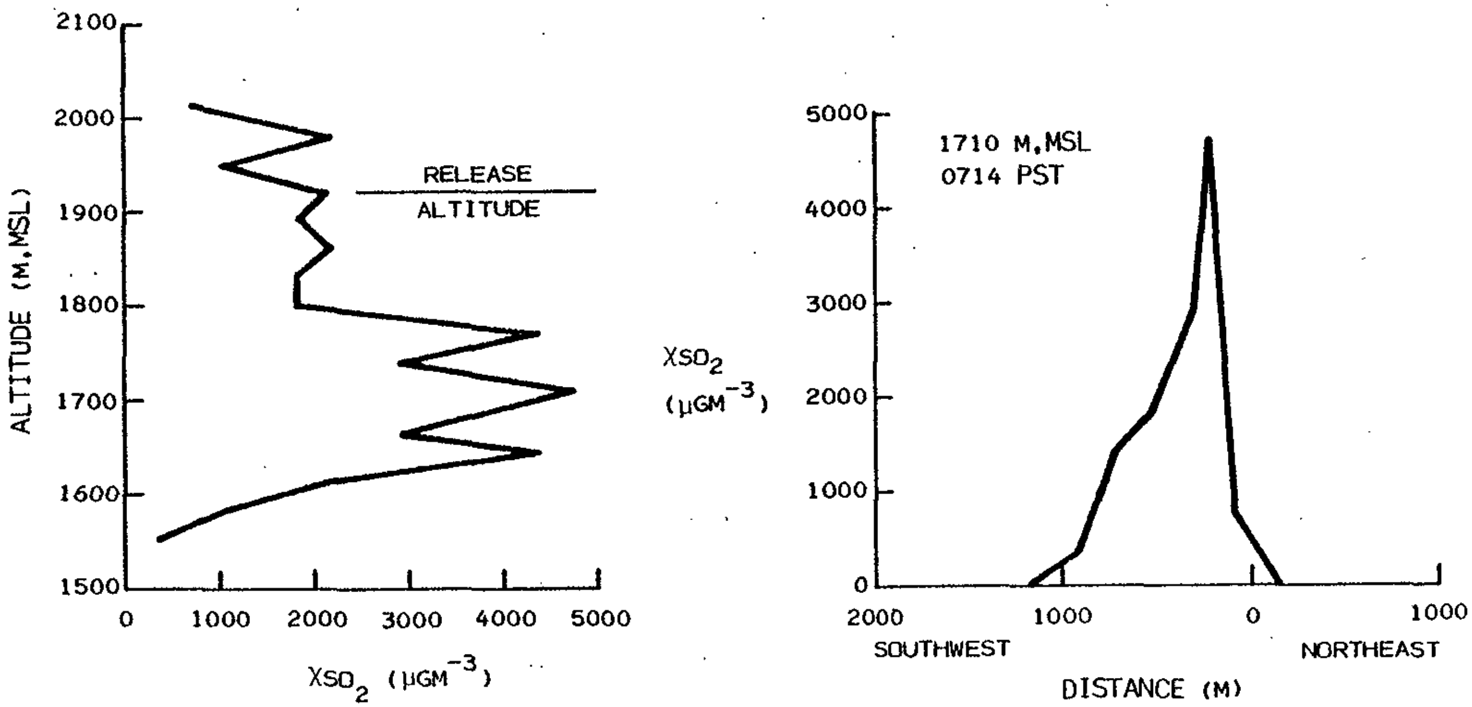


Figure 4.11-8 Vertical and horizontal plume centerline distributions for Test 11, Set 1.

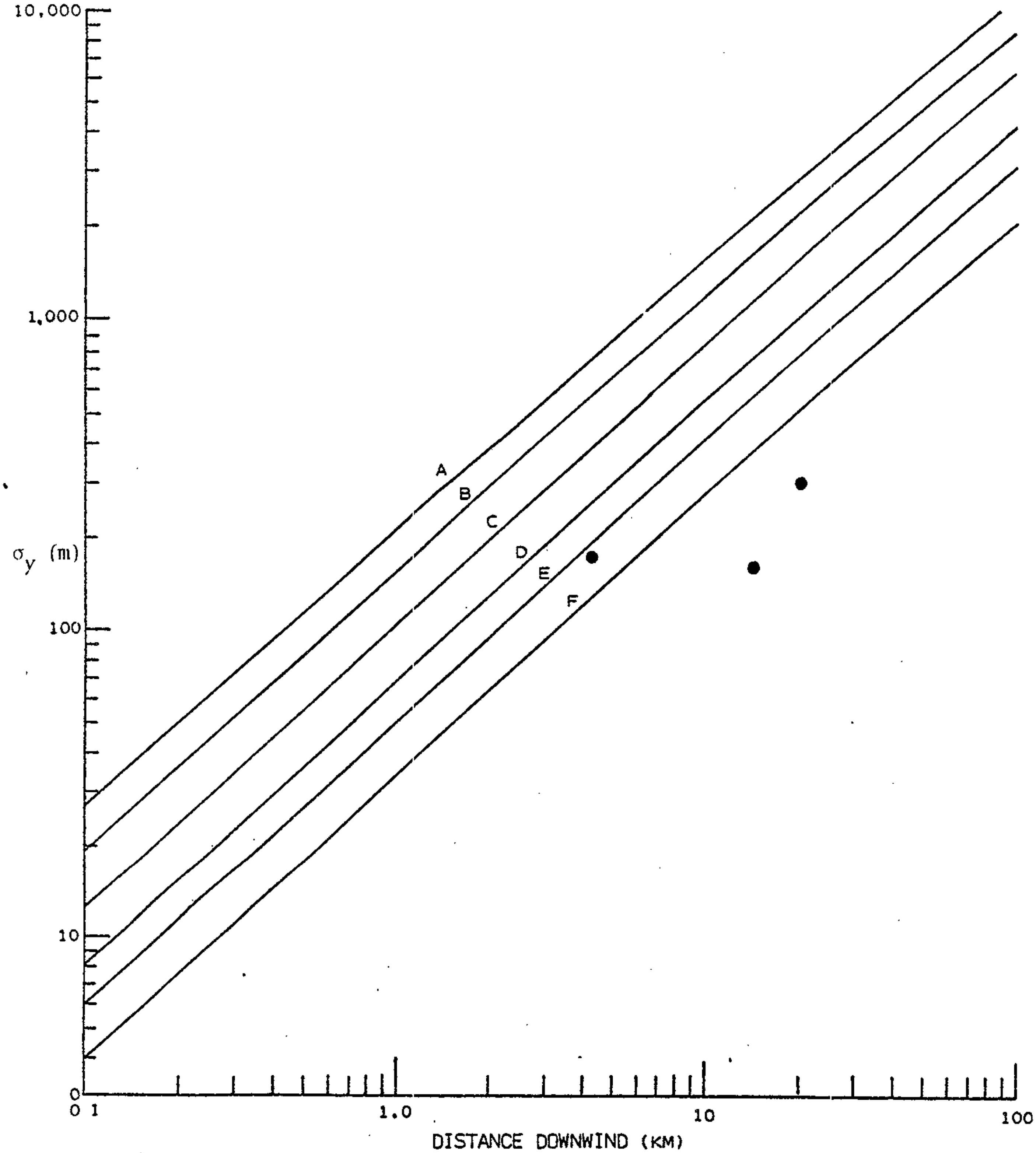


Figure 4.11-9 Measured values of σ_y and σ_z for Test 11.

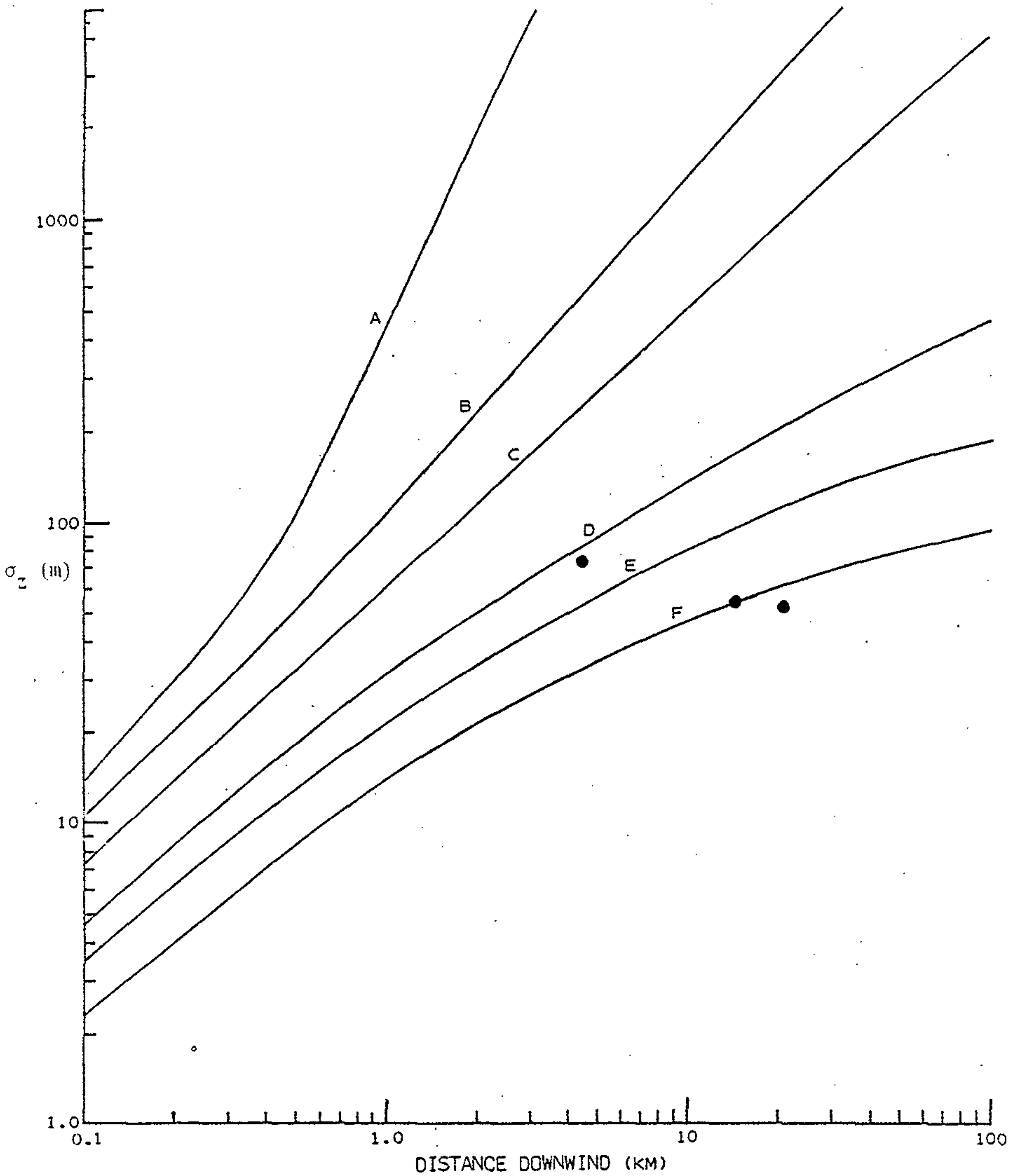


Figure 4.11-9 (Cont'd)

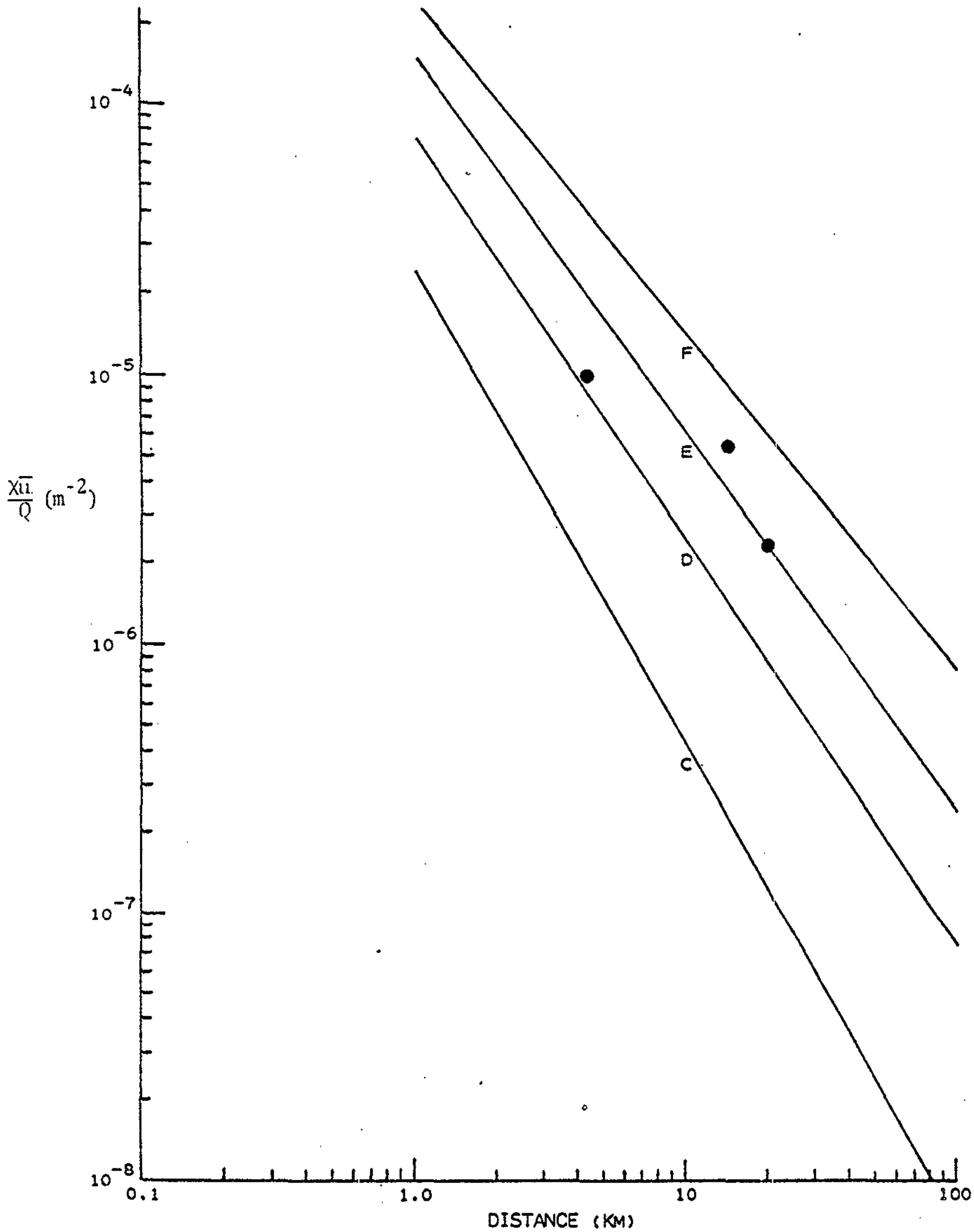


Figure 4.11-10 Measured values of $\frac{X\bar{u}}{Q}$ for Test 11.

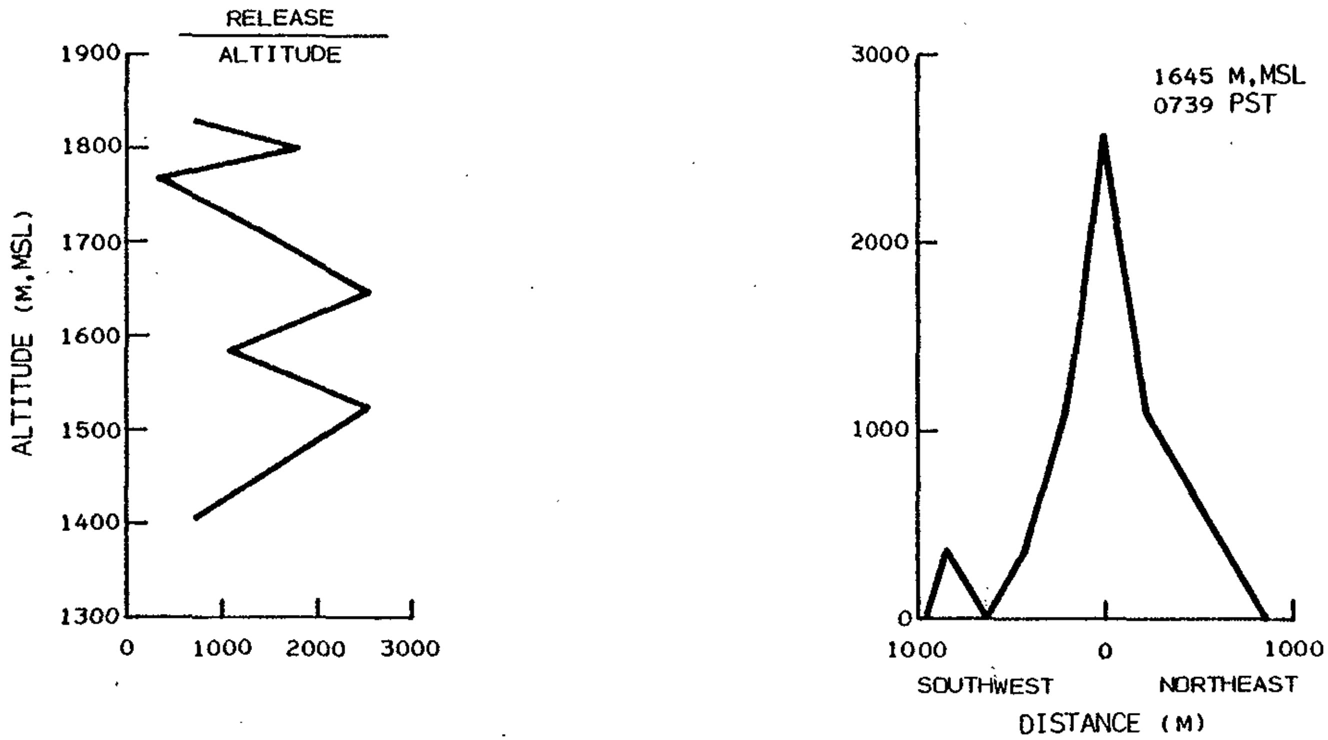


Figure 4.11-11 Vertical and horizontal plume centerline distributions for Test 11, Set 2.

E-F stability is indicated by the value of $\frac{X\bar{u}}{Q}$, as shown in Figure 4.11-10.

The third set of crosswind patterns was made about 20 km from the release point over the terrace separating the Thompson River and the Cornwall Hills on a line paralleling Highway 1. These measurements were made between 0750 and 0800 PST at altitudes from 1405 to 1588 m MSL. The maximum measured concentration, equivalent to 1099 μgm^{-3} was found at 1525 m. The vertical and horizontal distributions at the plume centerline are given in Figure 4.11-12. It can be seen that the bulk of plume appears to be at about the same altitude as found during Set 2. The values of σ_y and σ_z are plotted in Figure 4.11-9. The horizontal value apparently increased a good deal between Sets 2 and 3, while σ_z shows little change. The value of $\frac{X\bar{u}}{Q}$, plotted in Figure 4.11-10 falls on the curve nominal for E stability.

4.11.6 Aerial SF_6 Measurements. Ten one-minute aerial grab samples were taken during the test. The locations are shown in Figure 4.11-13 and pertinent information is given in Table 4.11-2. The sampling pattern consisted of two arcs, 10 and 14 km from the release point. The data from the first arc suggest a possible split plume, as higher concentrations are found at either end of the arc: over the divide between Ambusten and Medicine Creeks northwest of Cornwall Mountain, and near the saddle between Medicine and Cornwall Creeks. This is the same saddle through which the southern portion of the Test 8 plume passed. The maximum concentration was found to be 348 μgm^{-3} in samples 11H1 and 11H5. These samples were both taken at altitudes of 60 m AGL, though their MSL altitudes vary by 400 m. Three of the four samples from the second arc showed threshold concentrations of less than 22 μgm^{-3}. These samples were taken at altitudes as low as 1220 m MSL or about 700 m below plume altitude and at least 300 m below the ridgeline directly upwind.

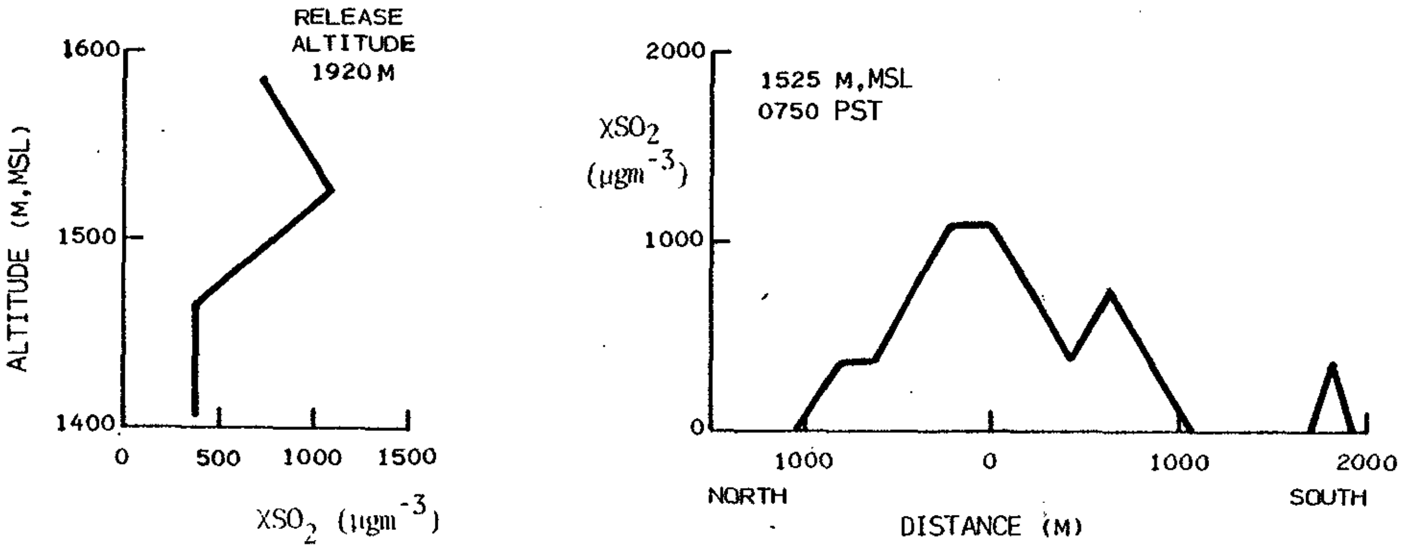


Figure 4.11-12 Vertical and hotizontal plume centerline distributions for Test 11, Set 3.

Table 4.11-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	NTP
11H1	9.1	1985	60	0712	1	348	423
11H2	10.2	1830	60	0715	1	<22	<27
11H3	10.5	1710	60	0718	1	0	0
11H4	9.7	1495	60	0721	1	<22	<27
11H5	10.2	1585	60	0724	1	348	423
11H6	9.5	1710	60	0727	1	238	290
11H7	12.1	1280	155	0750	1	<22	<27
11H8	14.1	1220	245	0753	1	<22	<27
11H9	14.0	1220	245	0756	1	<22	<27
11H10	15.0	1220	245	0759	1	0	0

Table 4.11-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3}) Ambient	NTP
11S1-11S10	Data Loss	Maximum 1 hr concentration was equivalent to no more than 144 μgm^{-3} or 175 μgm^{-3} (NTP)					
11T10	3.8	1050	0705	0747	42	0	0
			0747	0819	32	0	0
			0819	0906	47	0	0
11T11	3.2	1130	0715	0755	40	0	0
			0755	0830	35	0	0
			0830	0918	48	0	0
11T18	3.2	1220	0720	0740	20	0	0
			0740	0824	44	0	0
			0824	0912	48	0	0
11T19	4.0	1220	0727	0809	42	0	0
			0809	0834	25	0	0
			0837	0930	53	0	0
11T20	5.2	1250	0734	0804	30	0	0
			0804	0840	36	0	0
			0845	0945	60	0	0
			0740	0830	60	0	0
			0830	0930	60	0	0

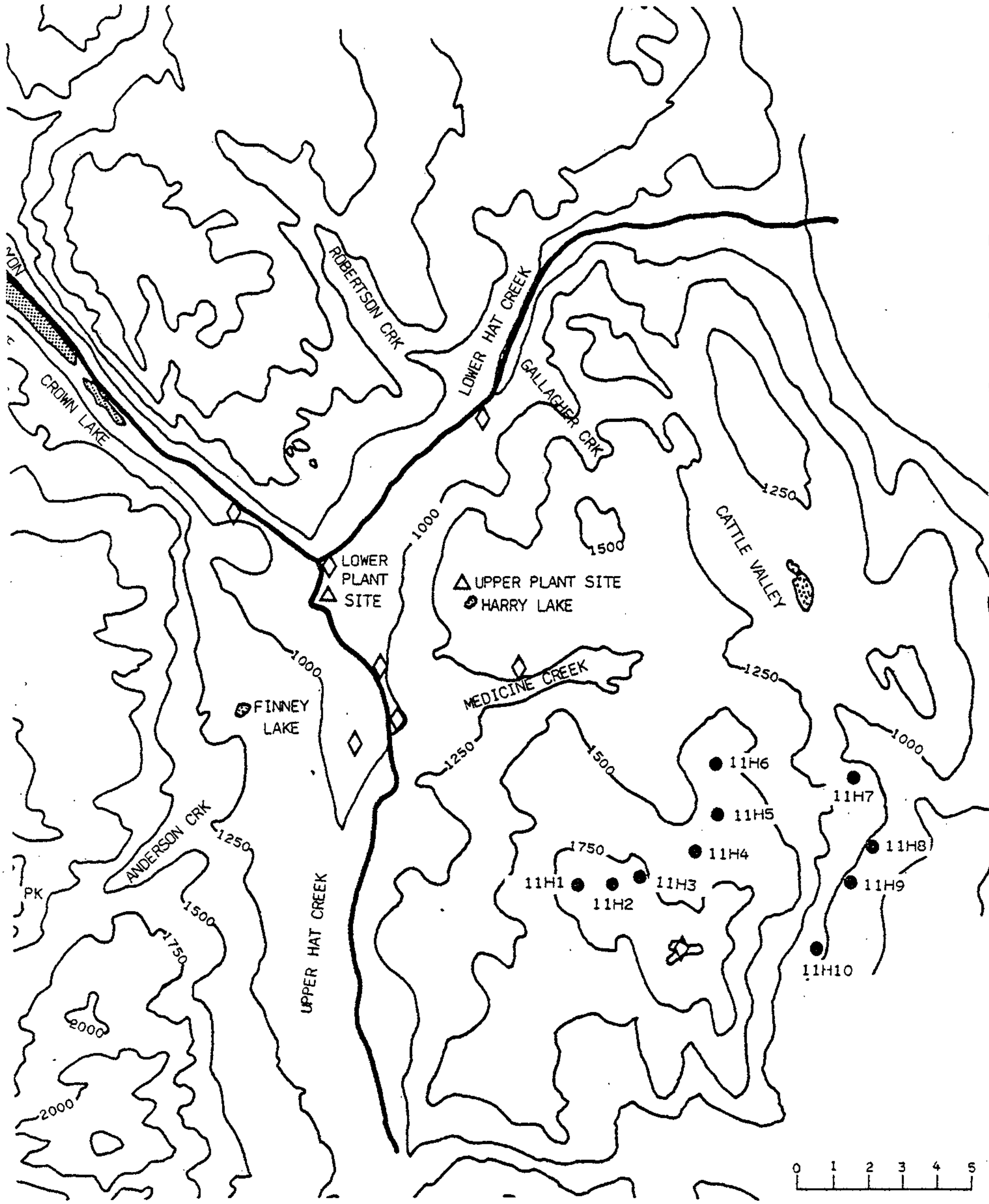


Figure 4.11-13 Location of aerial SF_6 measurements for Test 11.

4.11.7 Surface SF_6 Measurements. A total of 15 ground samplers was deployed for this test. The locations are shown in Figure 4.11-14. Supplementary information is supplied in Table 4.11-3. A partial data loss for samplers 11S1 through 11S9 precludes complete analysis of the concentrations from these sites. However, the available data do show that no sampler received more than 144 μgm^{-3} for a one-hour average. No measurable SF_6 was found at the proposed plant site or in any of the samples taken along Medicine Creek.

4.11.8 Turbulence Measurements. The turbulence measurements available from Test 11 come from the three sets of oil-fog crosswinds which may be located in Figure 4.11-7. The turbulence and intermittence measurements are displayed vs. altitude in Figure 4.11.-15. Sets 1 and 3 showed moderate turbulence values associated with slightly stable to neutral dispersion conditions and showed little change with altitude. Set 2 showed high rates of turbulence dissipation (a measurement to which the author will readily attest) and an apparent tendency to increase at lower altitudes.

Intermittence values were also moderate during Sets 1 and 3. Those from Set 2 are slightly greater, and represent very high values when consideration is given to the heavy turbulence measured here. No trends with altitude were readily apparent.

4.11.9 Summary of Test 11. Test 11 was conducted from the upper plant site. The release altitude was 1920 m MSL assuming a 183 m stack. Meteorological conditions at plume height were characterized by northwest winds at speeds of 7-8 m/s and near neutral stability conditions which extended to the surface. The coning tracer plume moved rapidly southeast up Medicine Creek. Aerial SF_6 data indicate the plume split here with one portion passing out towards the east through one of the gaps in the

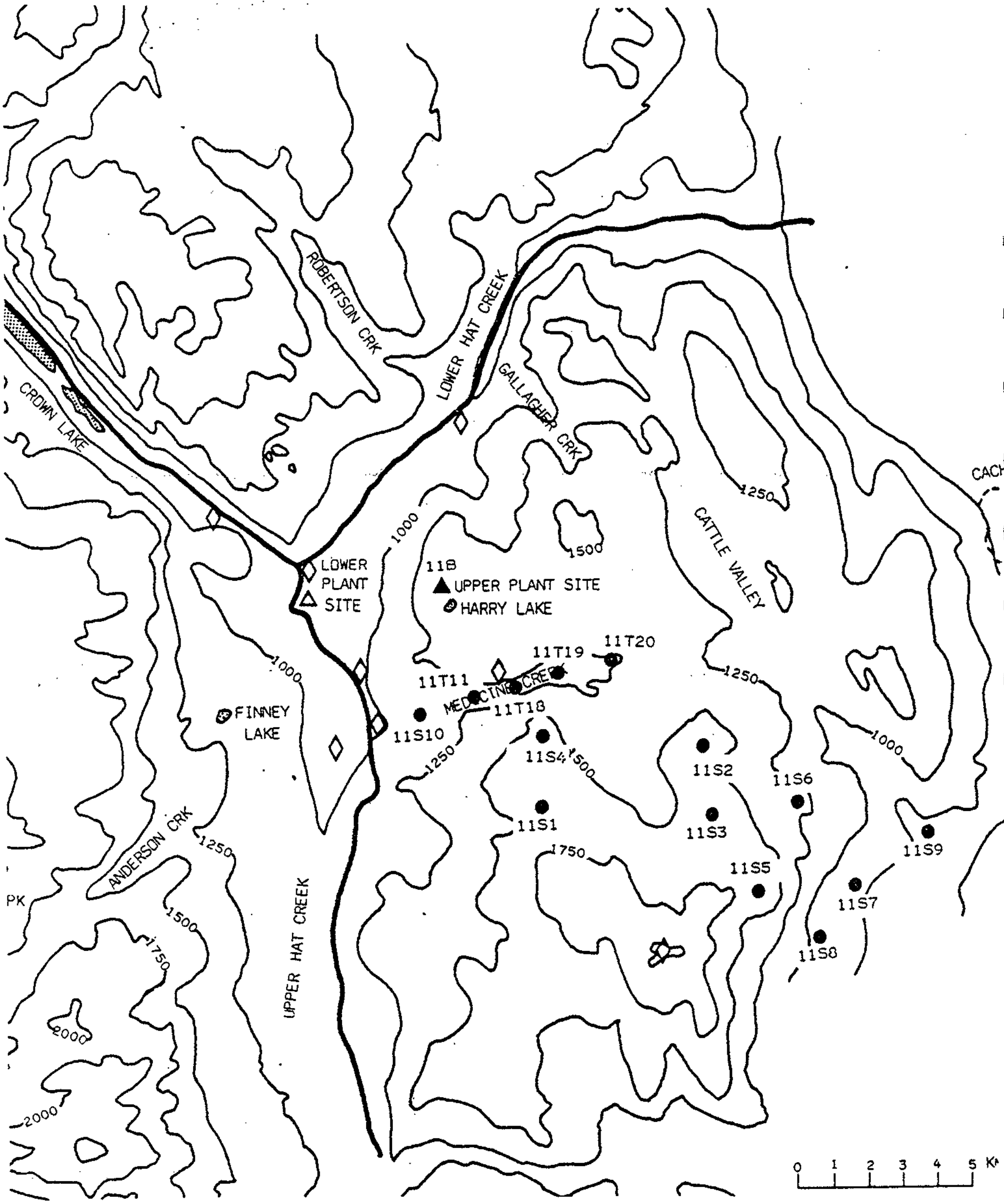


Figure 4.11-14 Location of surface SF_6 samplers for Test 11.

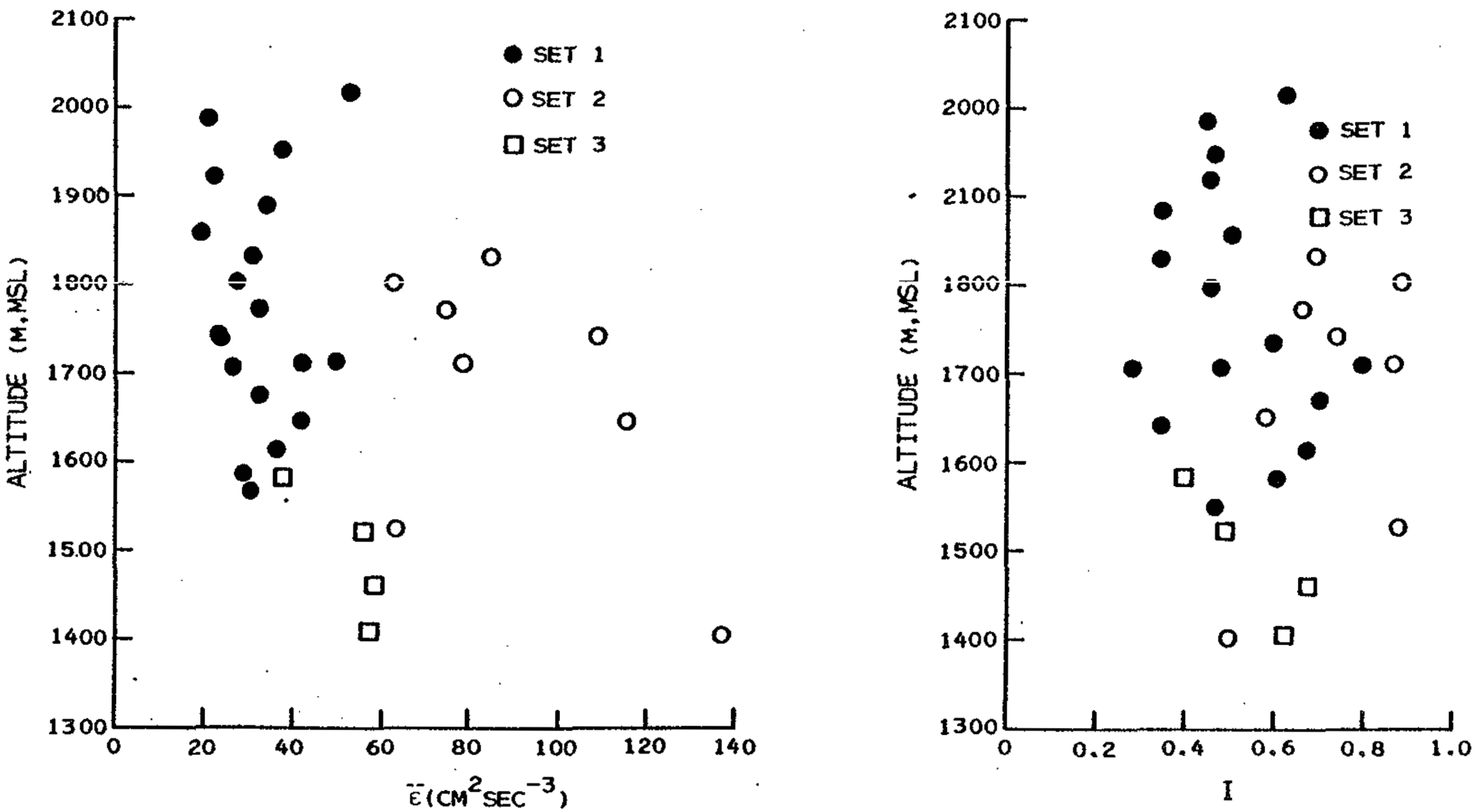


Figure 4.11-15 Turbulence measurements vs. altitude, Test 11.

ridgeline, and the other continuing south on the west side of the Cornwall Hills. Some downward mixing was noted in the eastward moving portion as it passed over the steep slopes and out over the Thompson River Gorge. Measurable aerial SF_6 concentrations were found, over the slopes, as much as 400 m below plume altitude. Although there was a partial data loss, the surface sampler data indicate some light surface impact with one hour of concentrations no more than 144 μgm^{-3}. Aerial oil-fog data indicate that the plume centerline sank about 300 m between the release point and the eastern slopes of the Cornwall Hills. The data also indicate surprisingly slow centerline dilution in view of the rather high winds and neutral atmosphere. Turbulence dissipation rates were found to be indicative of slightly stable conditions over Medicine Creek but suggested very rapid Class C dispersion over the steeper terrain of the leeward ridges.

These data suggest that the combination of relatively strong northwest flow and near neutral temperature structure caused rapid diffusion near the surface, producing one-hour surface concentrations of no more than 144 μgm^{-3}.

4.12 Test Number Twelve, August 10, 1976

Test 12 was conducted from the upper plant site during the morning of August 10, 1976. The stack height was assumed to be 183 m with a plume rise of 335 m, giving an effective emission altitude of 1890 m MSL. The meteorological conditions, characterized by very light winds and clear skies, were ideal for studying dispersion and fumigation within the Hat Creek circulation.

4.12.1 Synoptic Setting for Test 12. During the day, a ridge of high pressure, which was located over southwestern British Columbia in the morning, moved eastward and was east of the project area by evening. As a result, the low-level gradient wind veered from northerly in the morning to east-southeasterly in the afternoon. Early morning cloudiness consisted of scattered to broken altocumulus and cirrus. Small cumuli developed first over the hills during mid-morning and over the entire area eventually.

Surface and 700-mb maps are shown in Figure 4.12-1.

4.12.2 Meteorological Parameters for Test 12. The parameters measured during this test include temperature lapse rates, surface winds, and winds aloft. Temperature soundings were taken by mini-sonde, tethered sonde, and the NAWC tracer aircraft. The surface winds were monitored by the B. C. Hydro meteorological network. Winds aloft were measured by double tracked pilot balloon ascents.

The eleven temperature soundings available for this test are given in Figure 4.12-2. These soundings show a surface-based radiation inversion, extending to about 100 m AGL over the plant site in the early morning (0530 PST) and near neutral conditions aloft. Another sounding here at 0630 PST showed a shallow super-adiabatic surface layer and by 0655 PST, the inversion had been dissipated by surface heating. Other soundings at various locations show surface inversions, or their remnants, extending up to 400 m MSL over the Upper Hat Creek Valley, with neutral conditions aloft.

Surface wind data for this test can be located in Volume 2, Field Data. The data, available primarily for low-lying sites, indicate light down-valley flow until about 0830 PST, when up-valley flow commenced. Speeds ranged to 2.5 m/s.

The winds aloft data are presented as wind direction and wind speed time sections; Figures 4.12-3 and 4.12-4. It can be seen that, while the winds below about 250 m AGL were shifting from down-valley to up-valley between 0530 and 0930 PST, plume altitude

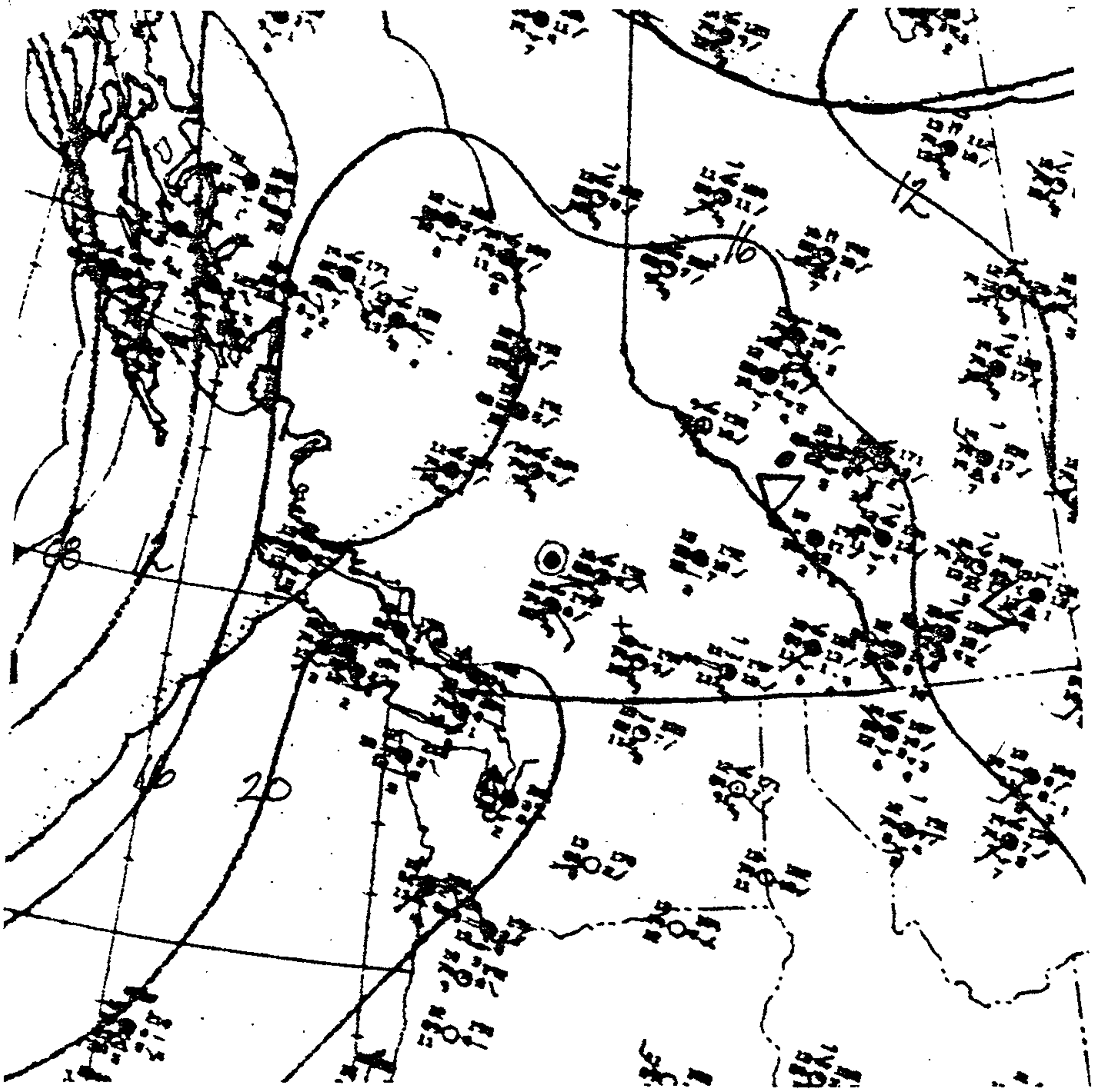


Figure 4.12-1 Surface and 500 mb maps for Test 12, August 10, 1976, 0400 PST.

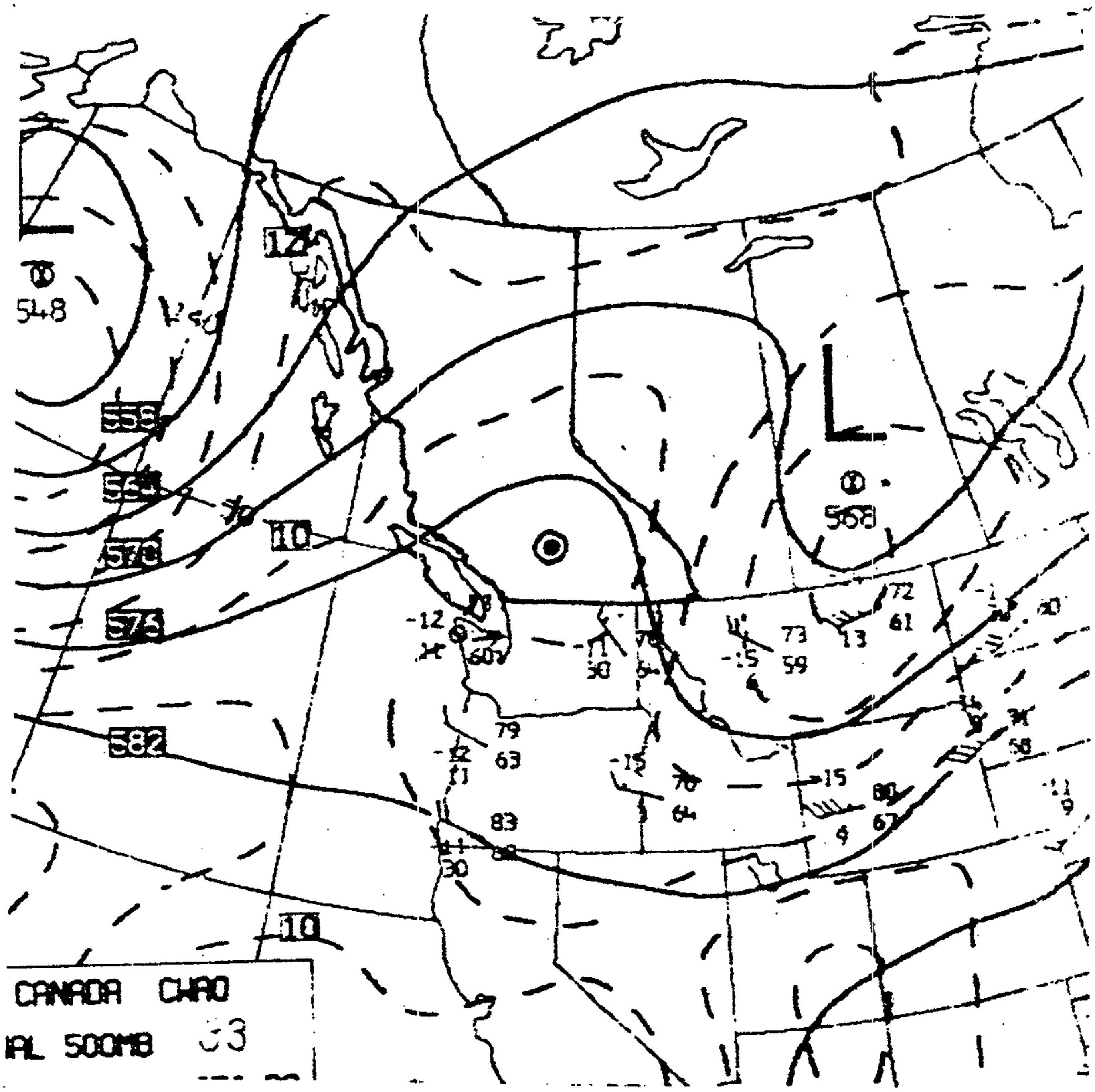


Figure 4.12-1 (Cont'd).

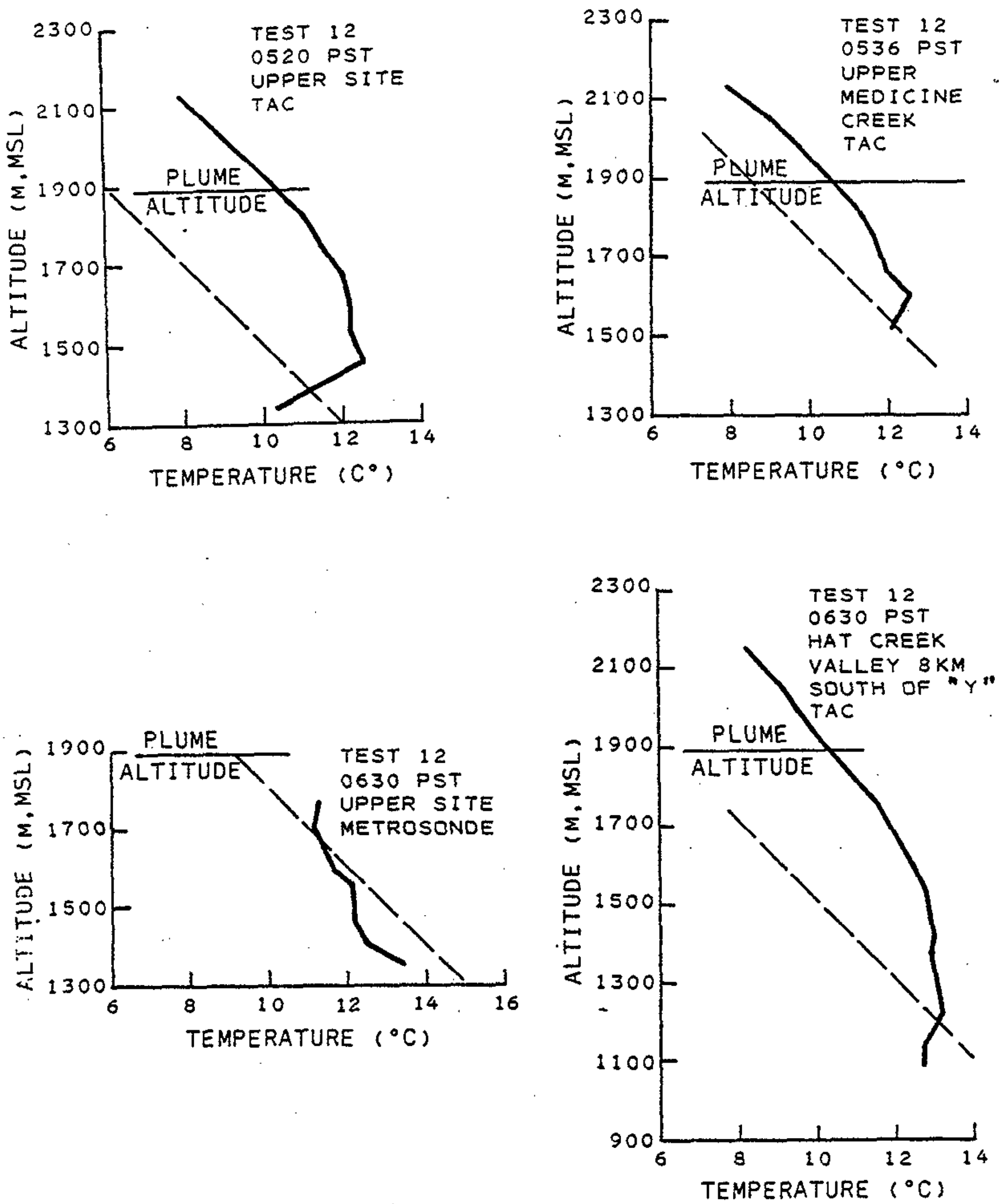


Figure 4.12-2 Vertical temperature profiles measured during Test 12.

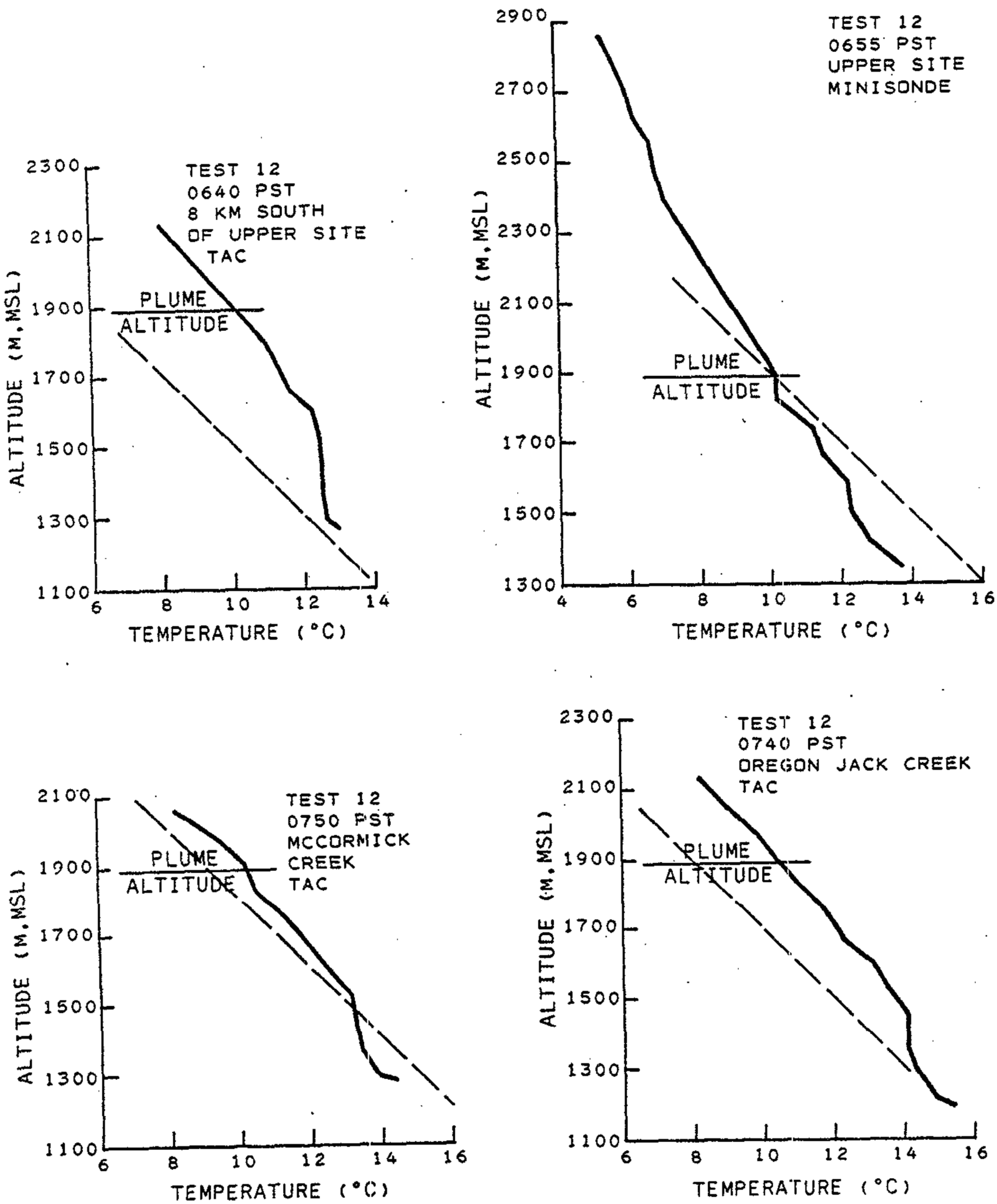


Figure 4.12-2 (Cont'd)

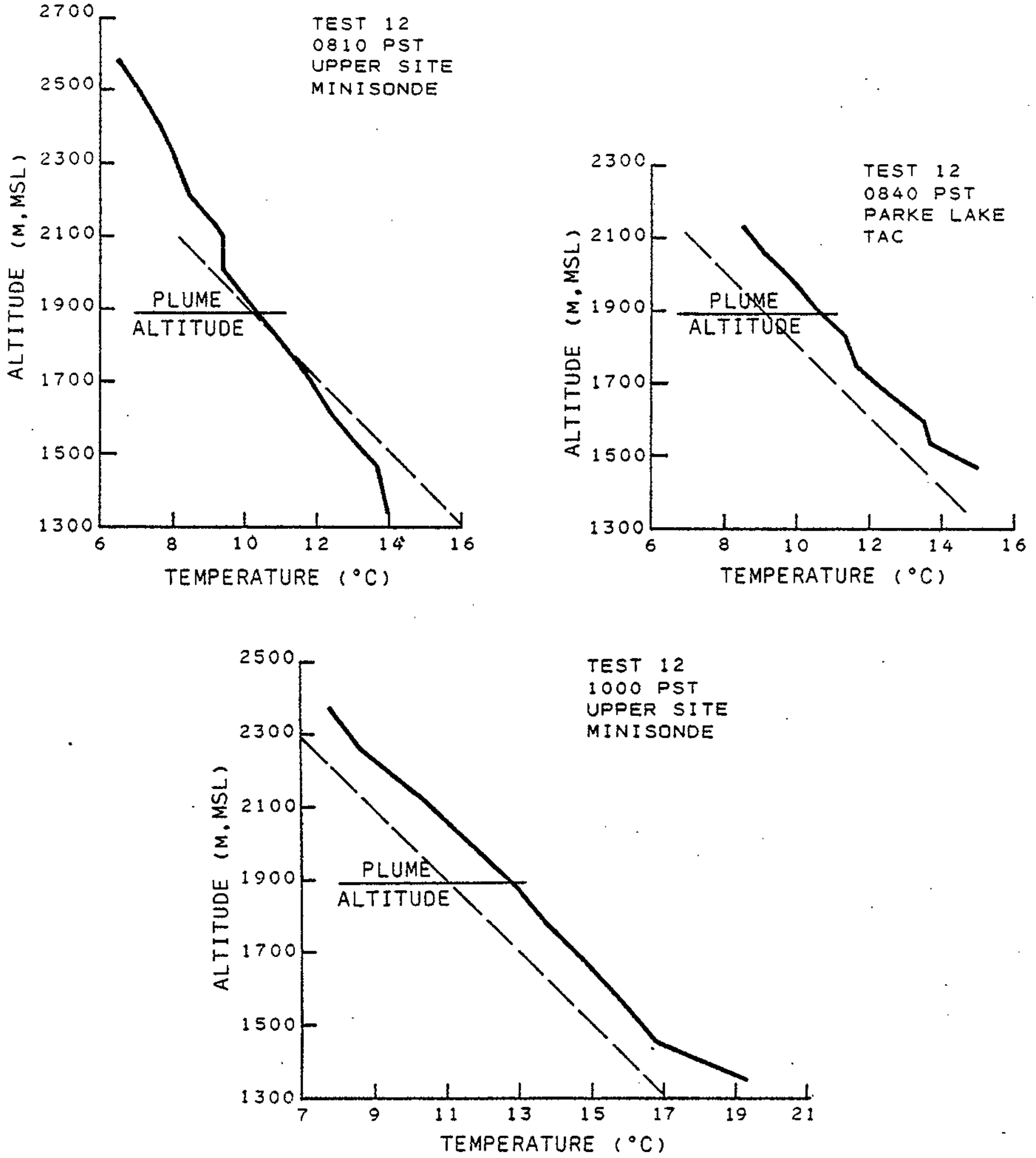


Figure 4.12-2 (Cont'd).

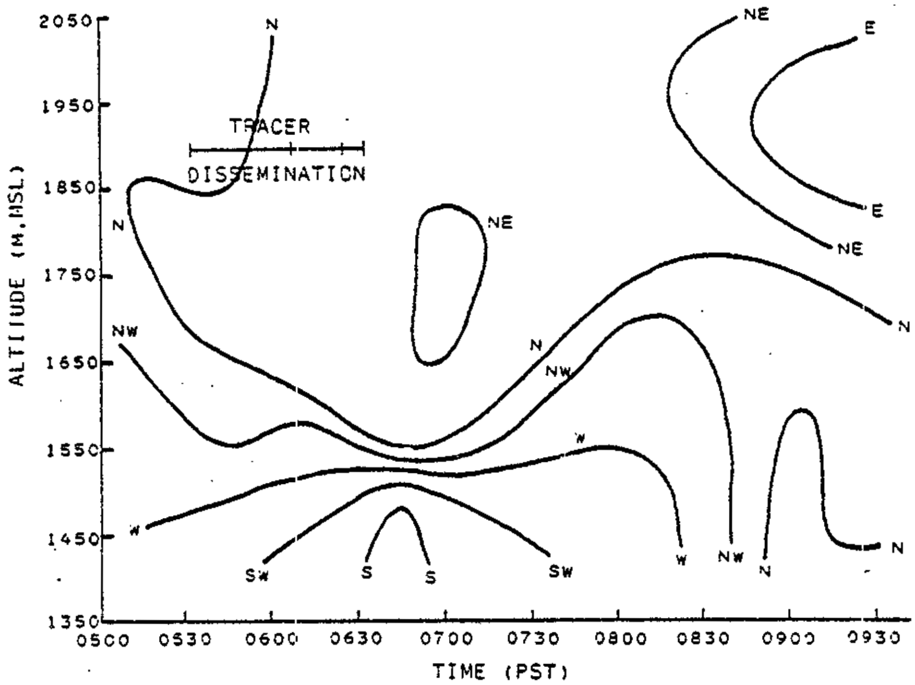


Figure 4.12-3 Time vs. altitude display of wind directions aloft measured during Test 12. Speeds are given in m/s.

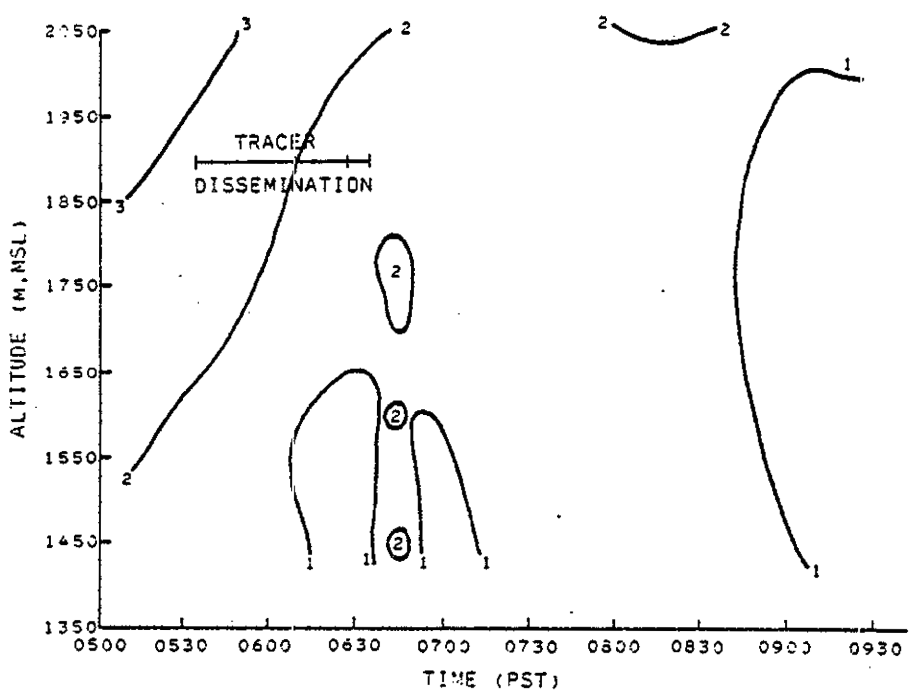


Figure 4.12-4 Time vs. altitude display of wind speeds aloft measured during Test 12. Speeds are given in m/s.

winds were from the north to northeast, becoming more easterly at about 0830. Wind speeds at release altitude were initially about 2.5 m/s and slowly decreased during the morning. Low-level wind speeds were generally less than 2 m/s.

4.12.3 Tracer Dissemination, Test 12. The pertinent tracer release parameters for this test are given in Table 4.12-1, below.

Table 4.12-1 Duration and source strength of tracer release number 12.

Location: Upper Site
Altitude: 1890 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0532	0632	18,387	5.11
Oil Fog (1)	0532	0607	109,800	52.3
Oil Fog (2)	0625	0632	N/A	N/A

4.12.4 Photographic and Visual Observations. The oil-fog plume initially drifted toward the south-southeast. However, the plume direction shifted more to the south and south-southwest after the first 15 minutes. Figure 4.12-5 shows an upwind-looking view of the stable plume as it passed over Ambusten Creek at 0622 PST. Southward transport along the eastern side of Upper Hat Creek Valley continued at a speed of 2 to 3 m/s for almost the next hour. The plume remained very stable during this period. Figure 4.12-6, taken at 0704 PST, shows that dispersion of the plume was slow enough that the track of the tracer aircraft remained visible several minutes after a crossing pass through the plume. At 0730 PST, Figure 4.12-7 shows that part of the plume had been transported toward the western side of Hat Creek Valley,

Figure 4.12-5 Photo, Test 12. Transport is towards the observer in this photo of the stable plume passing over Ambusten Creek. View is to the north, 0622 PST.

Figure 4.12-6 Photo, Test 12. Tracks of the tracer aircraft visible in the oil-fog demonstrate the very slow dispersion experienced by this plume. Transport is to the left, 0704 PST.

although the plume centerline was still generally east of Hat Creek. The leading edge of the plume at that time was near the intersection of Upper Hat Creek Valley and Oregon Jack Canyon, or about 17 km from the release site. After 0730 PST, the plume transport shifted toward the west, apparently in response to early morning solar heating of the western slopes of the valley. Figure 4.12-8, at 0759 PST, shows the plume near the western foothills of Hat Creek Valley and cumuli over the higher elevations. Fumigation of the western side of the plume began during the next 15 minutes, as shown in Figure 4.12-9. Many ripples and waves were developing on that part of the plume that was not fumigating (Figure 4.12-10). The fumigation process continued and, as shown in Figure 4.12-11, the diffuse plume was transported up the slopes and side canyons. By 0839 PST, the first smoke plume had become practically invisible, while the smaller second plume was beginning to fumigate south of Finney Lake (Figure 4.12-12). Plume outlines at selected times are shown in Figure 4.12-13.

4.12-5 Aerial Oil-Fog Measurements. The oil-fog measurements from Test 12 consist of two detailed sets of crosswind patterns, plus supplementary information gathered during soundings and turbulence transects. The location of the crosswind patterns are shown in Figure 4.12-14.

The first set of passes were flown directly over Medicine Creek, 3.7 km downwind, from 0550 and 0625 PST. Seventeen individual passes were made at altitudes between 1920 and 1710 m MSL. The maximum concentration measured during this set, equivalent to 54,409 μgm^{-3}, was found at 1800 m MSL, 90 m below release altitude. The additional passes flown at the centerline altitude are not reflected on either the plots of centerline distribution, which show only the concentrations from the first pass at a given altitude, nor directly in the calculation of $\frac{X\bar{u}}{Q}$ which used the mean value from two passes.

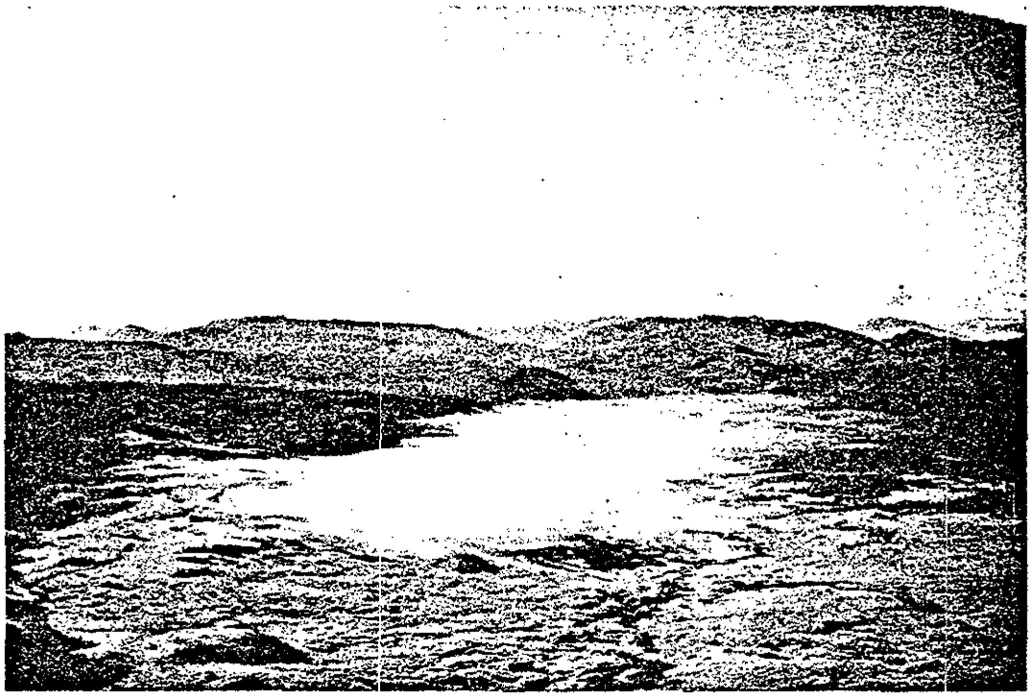


Figure 4.12-7 Photo, Test 12. By 0730 PST the plume was over the center of the valley as westward transport began. View is towards the south.

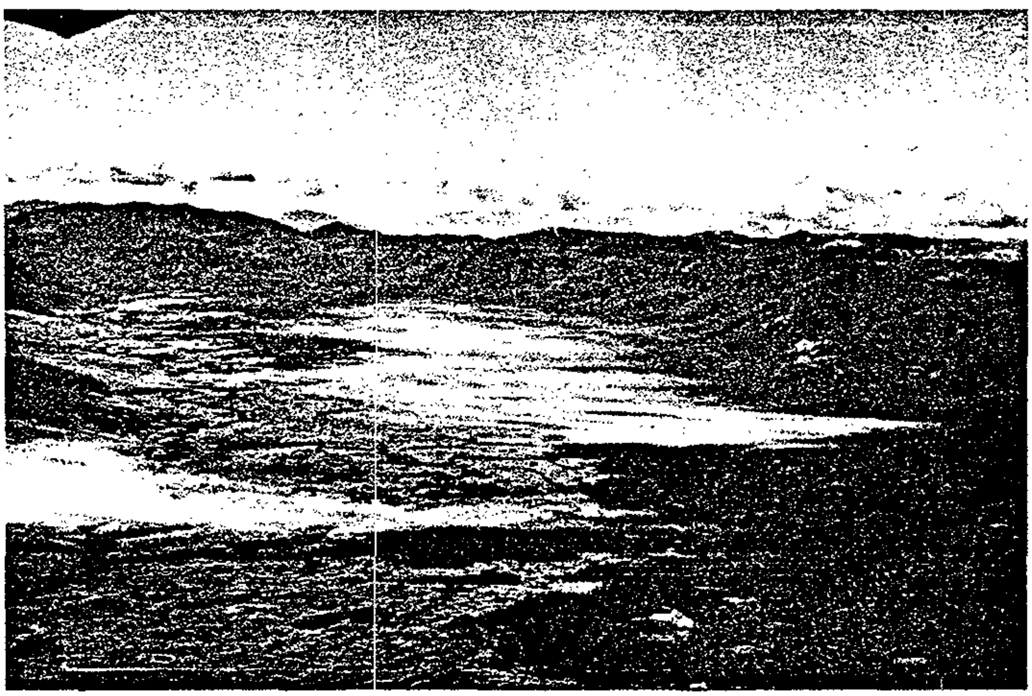


Figure 4.12-8 Photo, Test 12. Second oil-fog plume, lower left, shows wind shift since beginning of tracer release. First plume is approaching the western slopes of the valley. View is up-valley at 0817 PST.

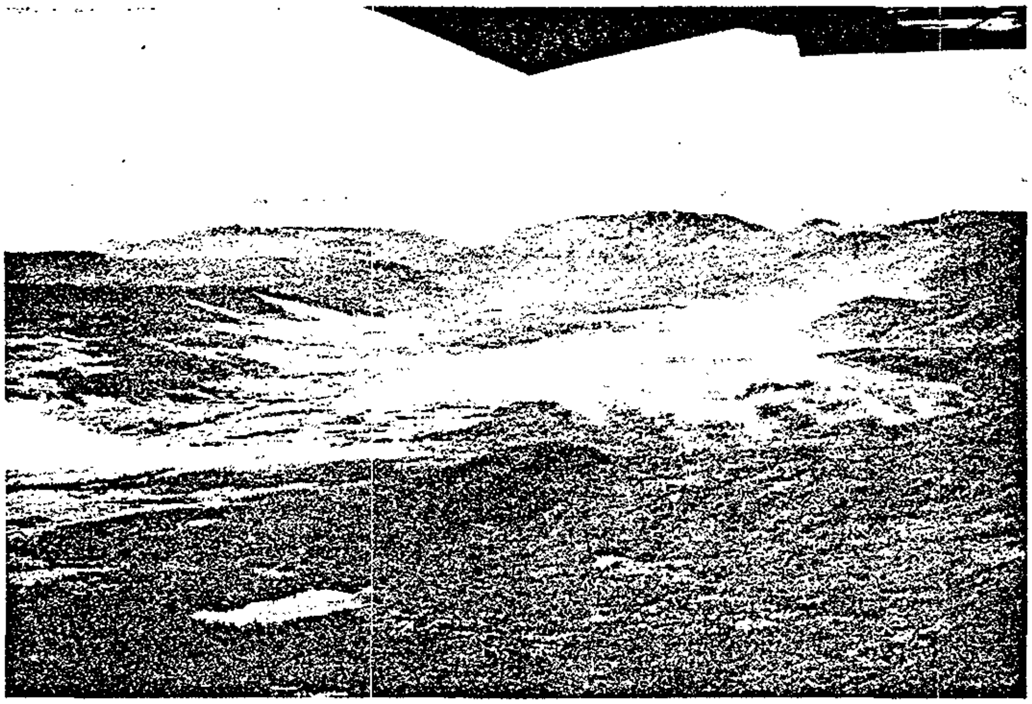


Figure 4.12-9 Photo, Test 12. The westernmost portions of the first plume (right) are fumigating as many waves form on the remainder. Second plume still appears stable as it passes over Finney Lake (lower left).

Figure 4.12-10 Photo, Test 12. View is up-valley at 0817 PST. A closer view of the fumigating plume looking southward along the west side of the valley at 0819 PST.

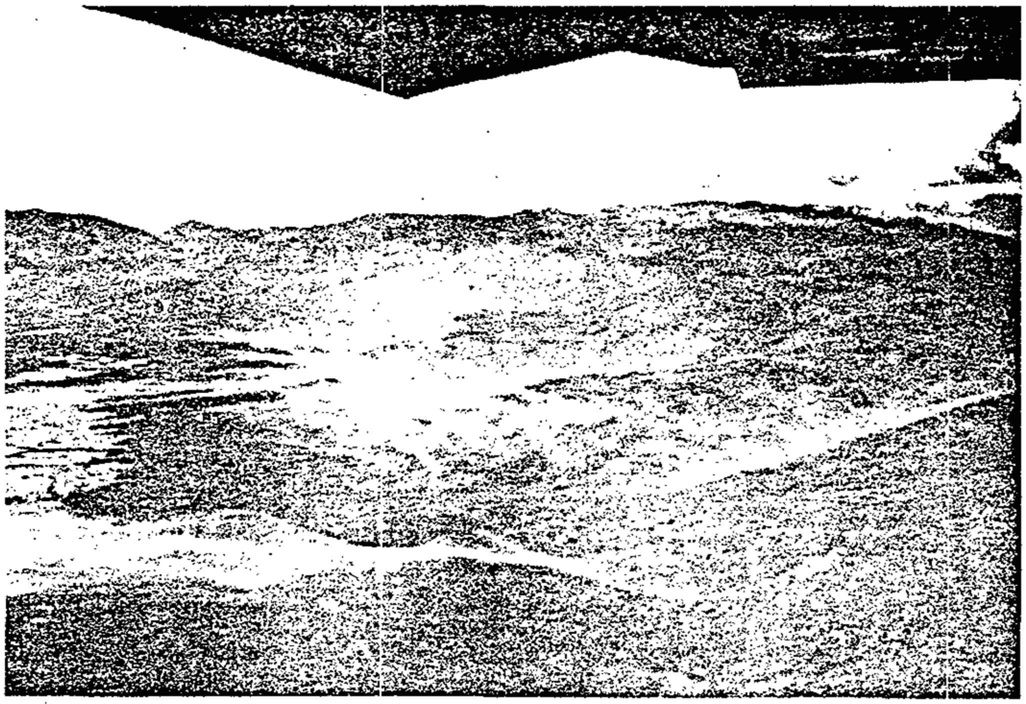


Figure 4.12-11 Photo, Test 12. By 0825 waves began to develop in the second plume as fumigated remnants of the first are transported rapidly up-slope. View is to the south.

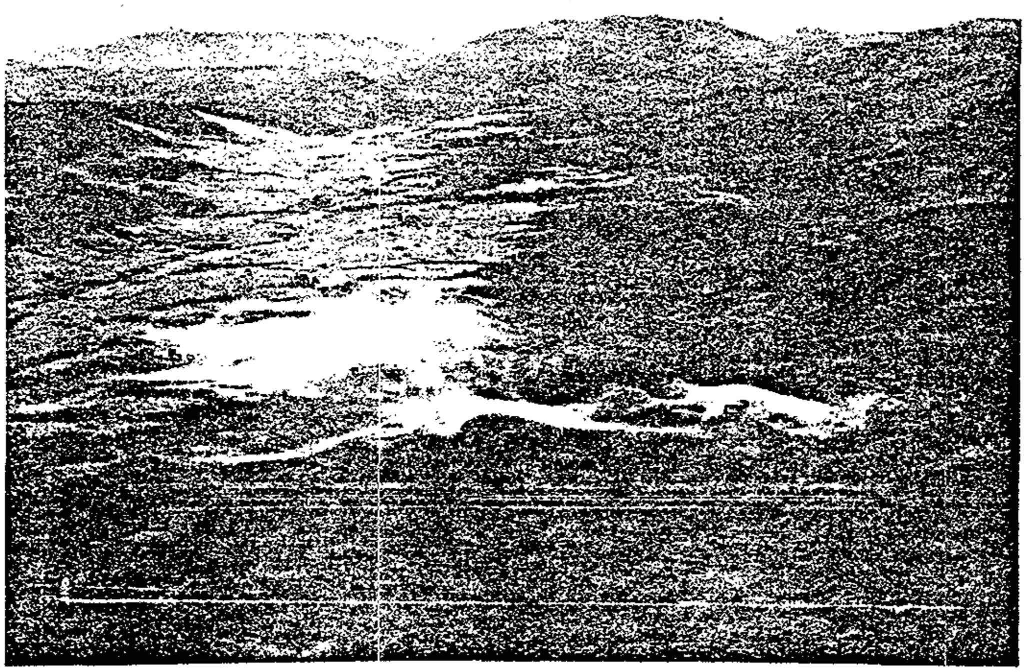


Figure 4.12-12 Photo, Test 12. The second plume is beginning to fumigate over the ridge just south of Finney Lake (lower left) in this photo taken at 0839 PST. Note that the first plume is now almost completely invisible. View is up-valley.

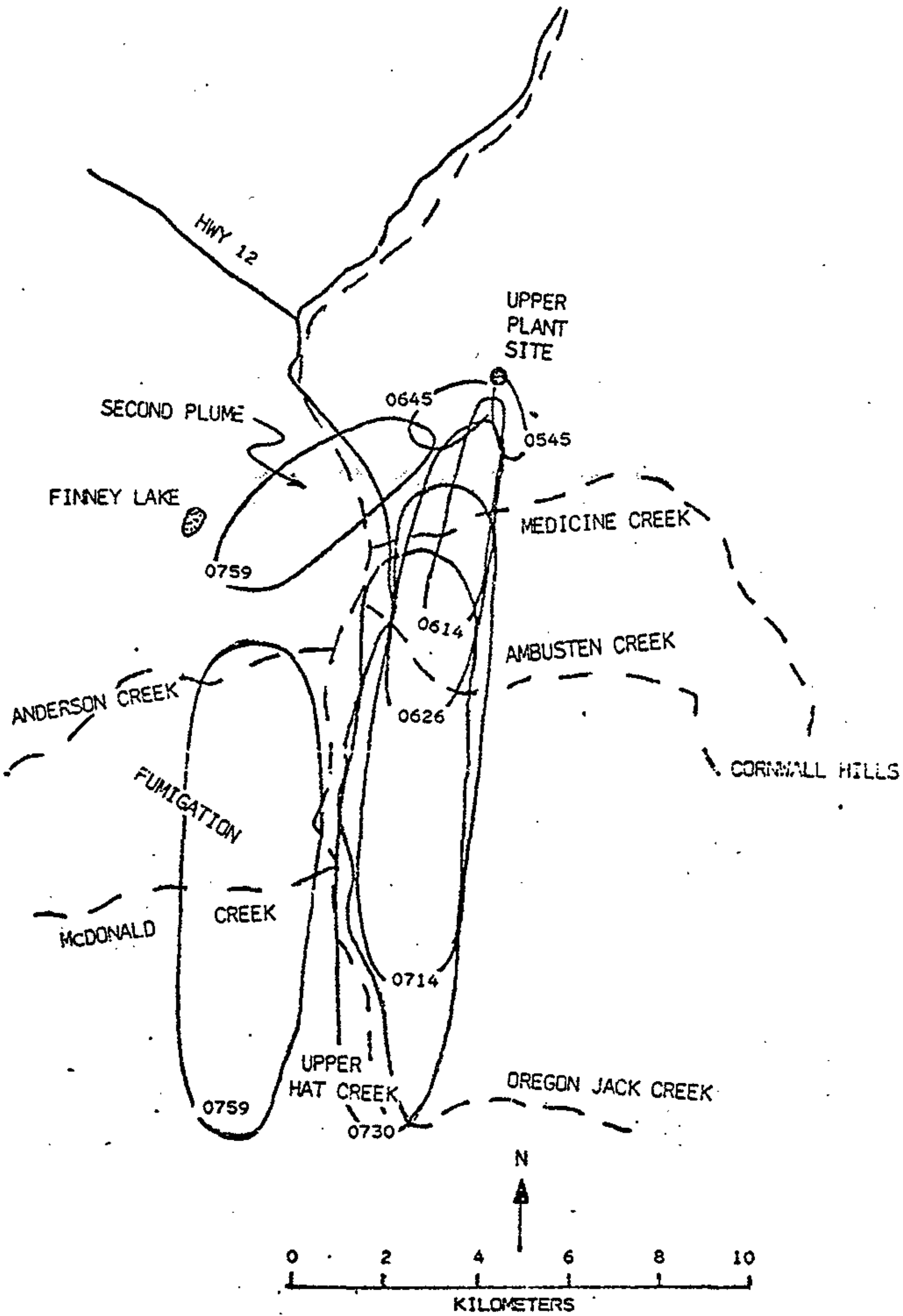


Figure 4.12-13 Plume outlines at various times during Test 12.

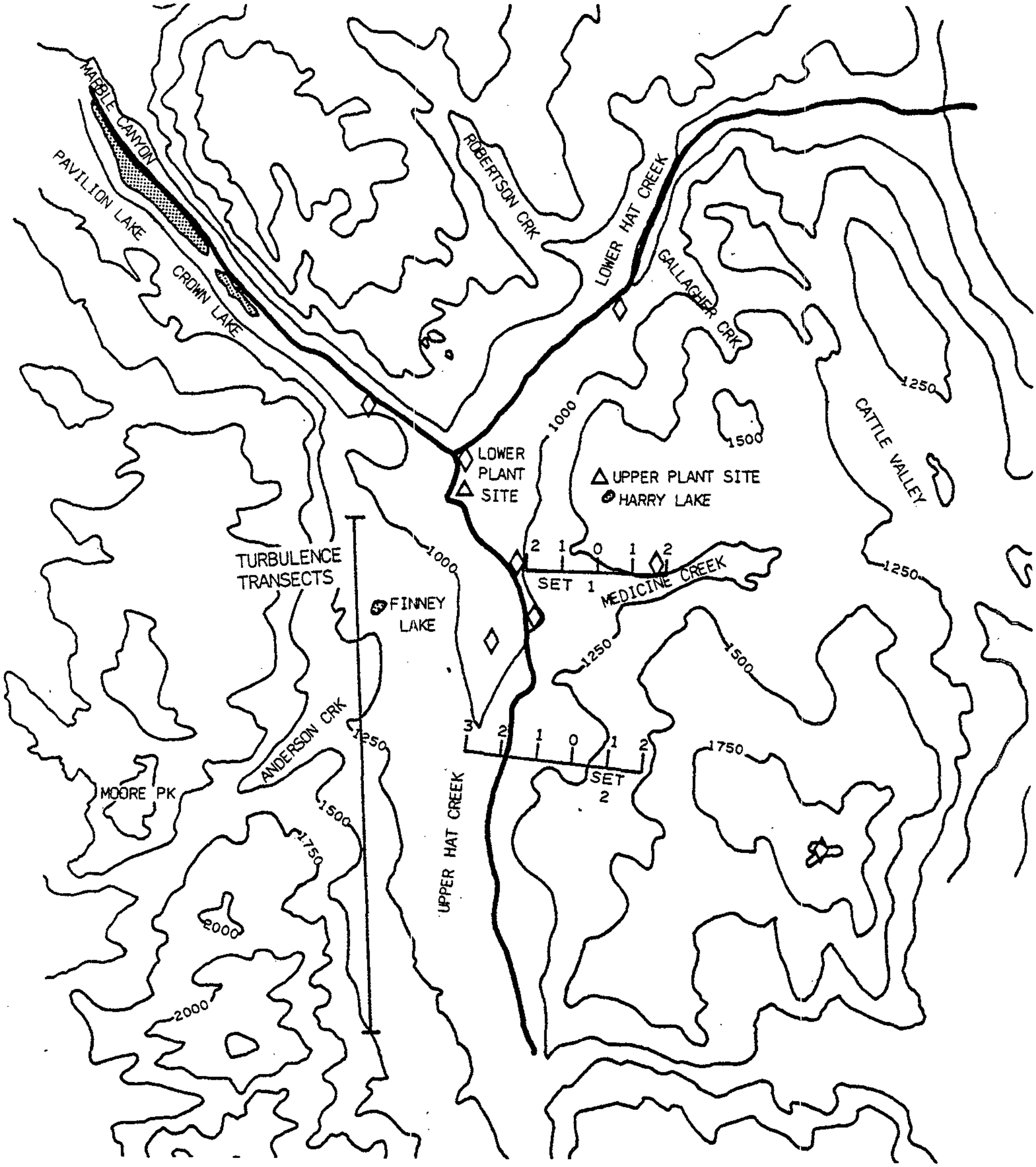


Figure 4.12-14 Locations of oil-fog crosswind patterns and turbulence transects, Test 12. Distances are in kilometers.

The vertical and horizontal centerline distributions are shown in Figure 4.12-15. The solid lines indicate values gathered during the first set of passes through the plume at this location, other values indicated are for maximum concentrations found on repeat passes near the centerline. The distributions show the plume to be confined to a layer about 200 m deep centered approximately 90 m below release altitude. Plume width was near 2 km.

The values for σ_y and σ_z computed from the aerial data are shown along with the standard curves in Figure 4.12-16. It can be seen that σ_y indicates neutral stability, while σ_z falls slightly below the standard value for very stable conditions. The normalized concentration, $\frac{X\bar{u}}{Q}$, computed from averaged maximum concentrations, is plotted in Figure 4.12-17. The value is nominal for slightly stable conditions.

The second set of crosswind patterns were flown 8.3 km from the release in the vicinity of Ambusten Creek. These passes, conducted from 0653 to 0725 PST, were flown between 1830 and 1680 m MSL. A maximum concentration of 30,506 μgm^{-3} was found at an altitude of 1710 m MSL during the initial passes through the plume. Subsequent passes near that altitude yielded a maximum measured concentration of 48,433 μgm^{-3} at 1725 m MSL. The vertical and horizontal centerline distributions are given in Figure 4.12-18. Selected values from the extra passes made near the centerline are also shown.

An indication of the westward movement of the centerline can be seen in the two horizontal plots. An analysis of centerline location on consecutive passes indicates a lateral speed of about 0.5 m/s.

The calculated values of σ_y and σ_z for Set 2 are presented in Figure 4.12-16. There is little change in either value from

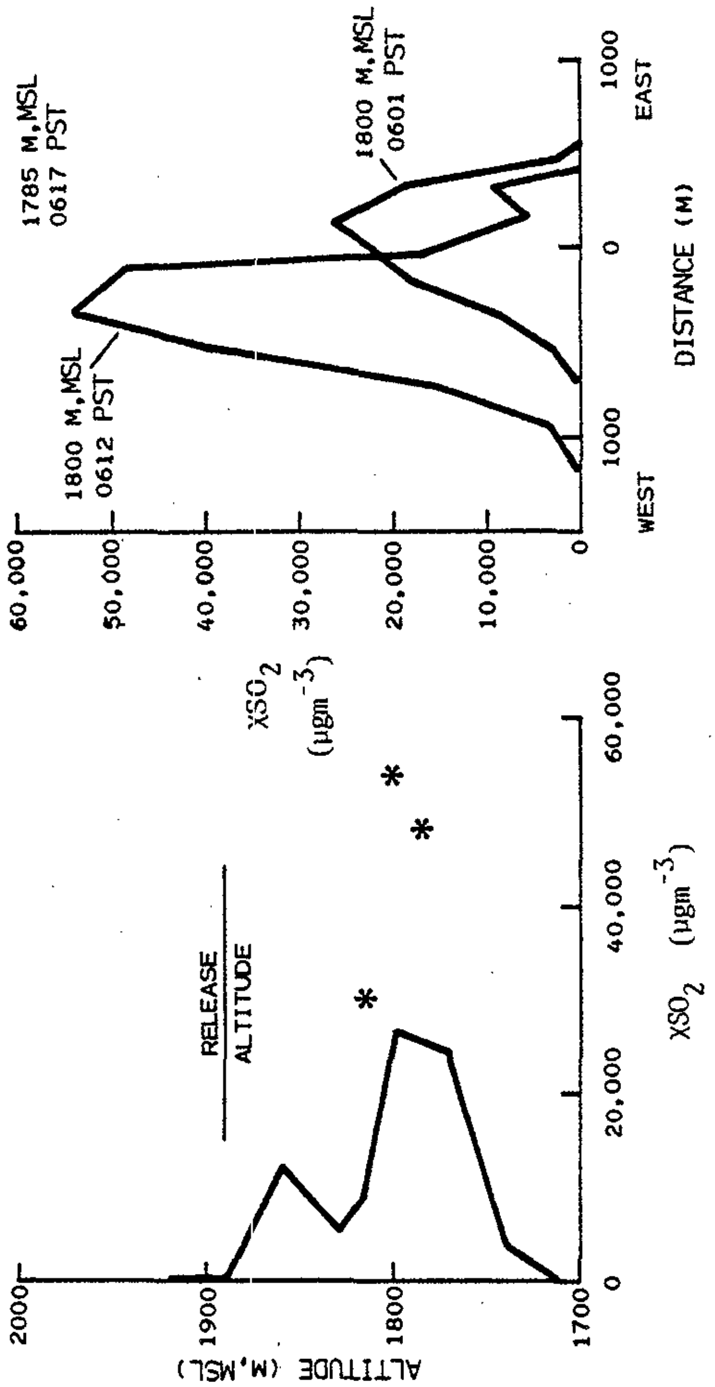


Figure 4.12-15 Vertical and horizontal plume centerline distributions, Test 12, Set 1.

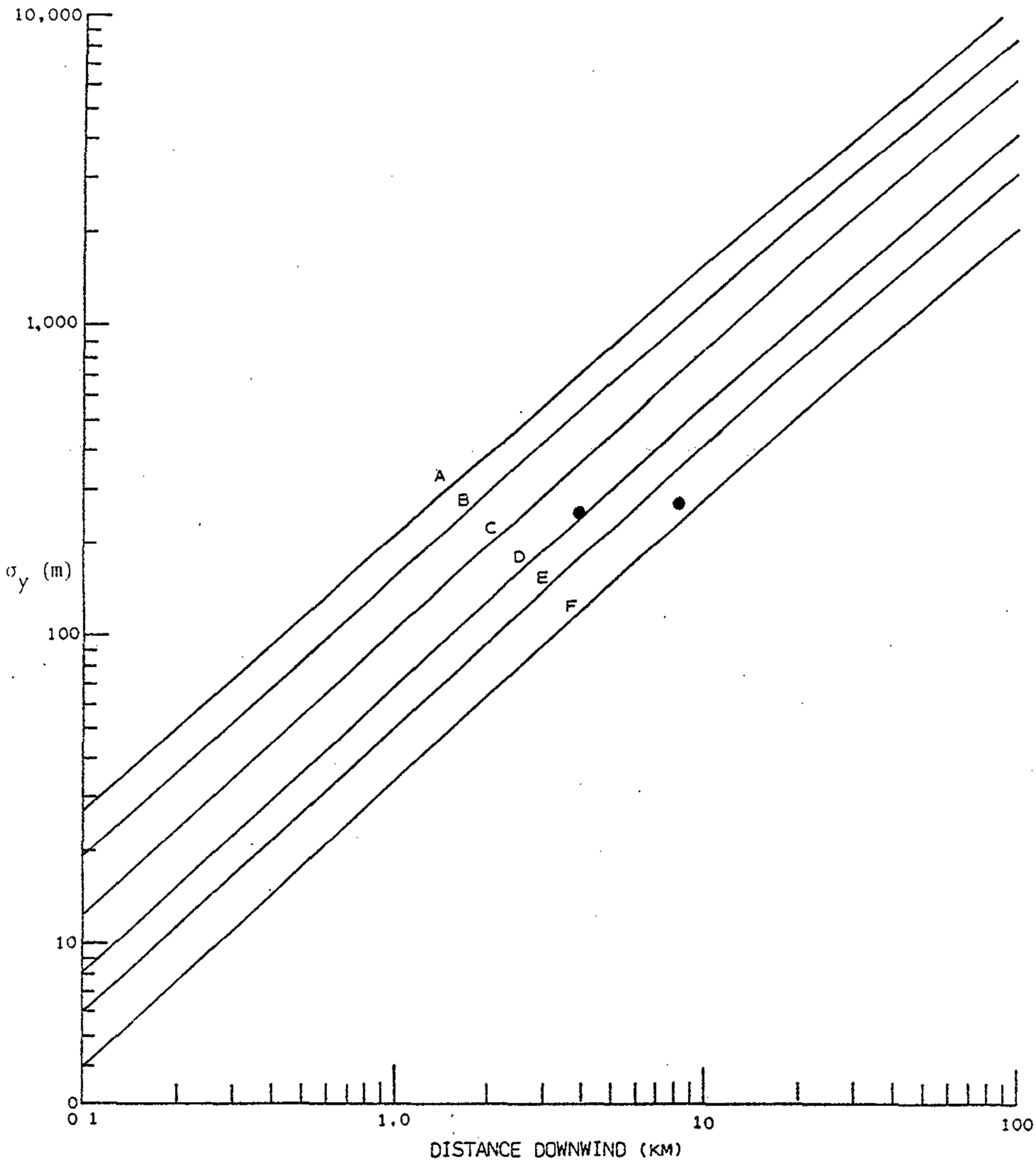


Figure 4.12-16 Measured values of σ_y and σ_z for Test 12.

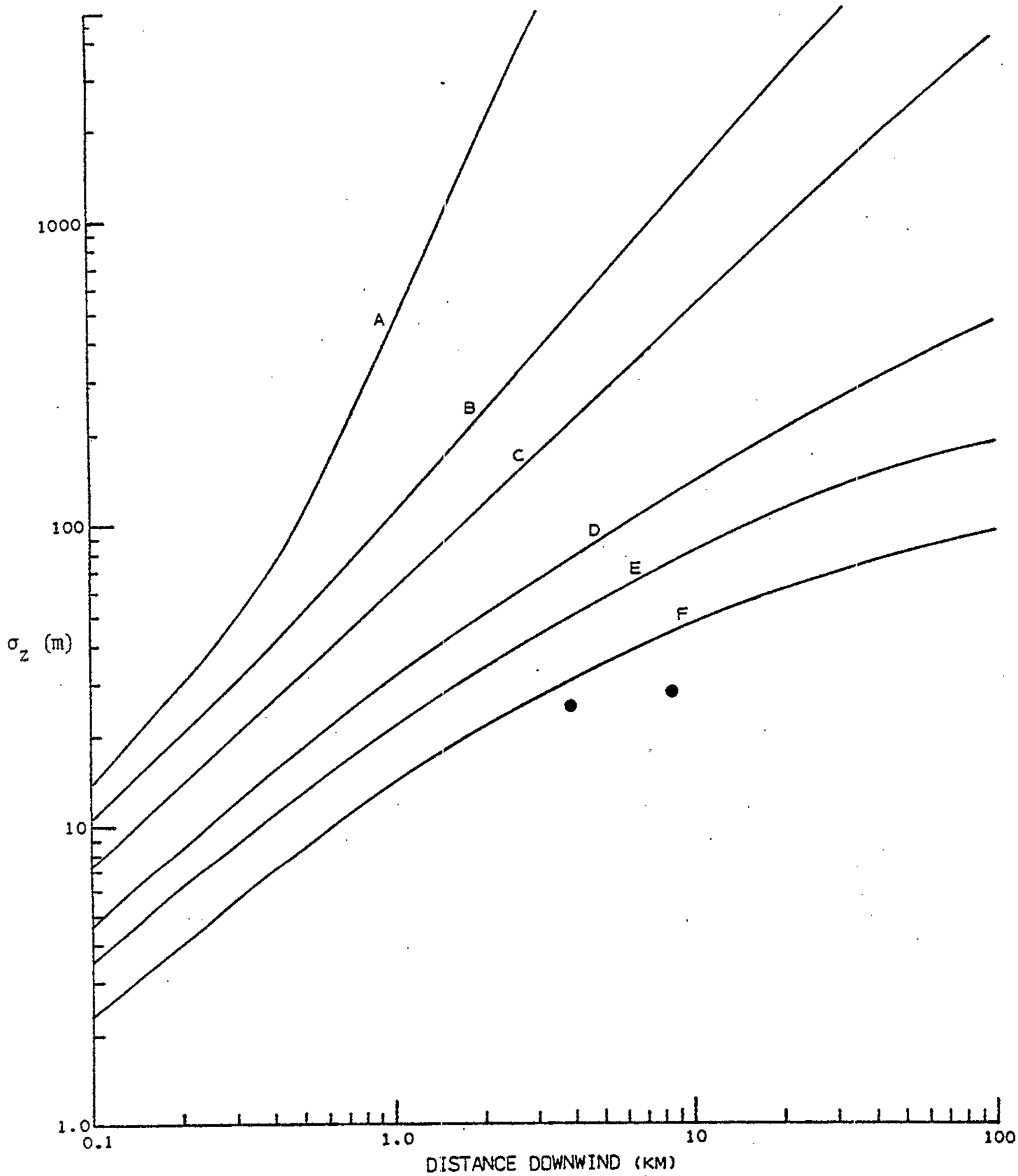


Figure 4.12-16 (Cont'd).

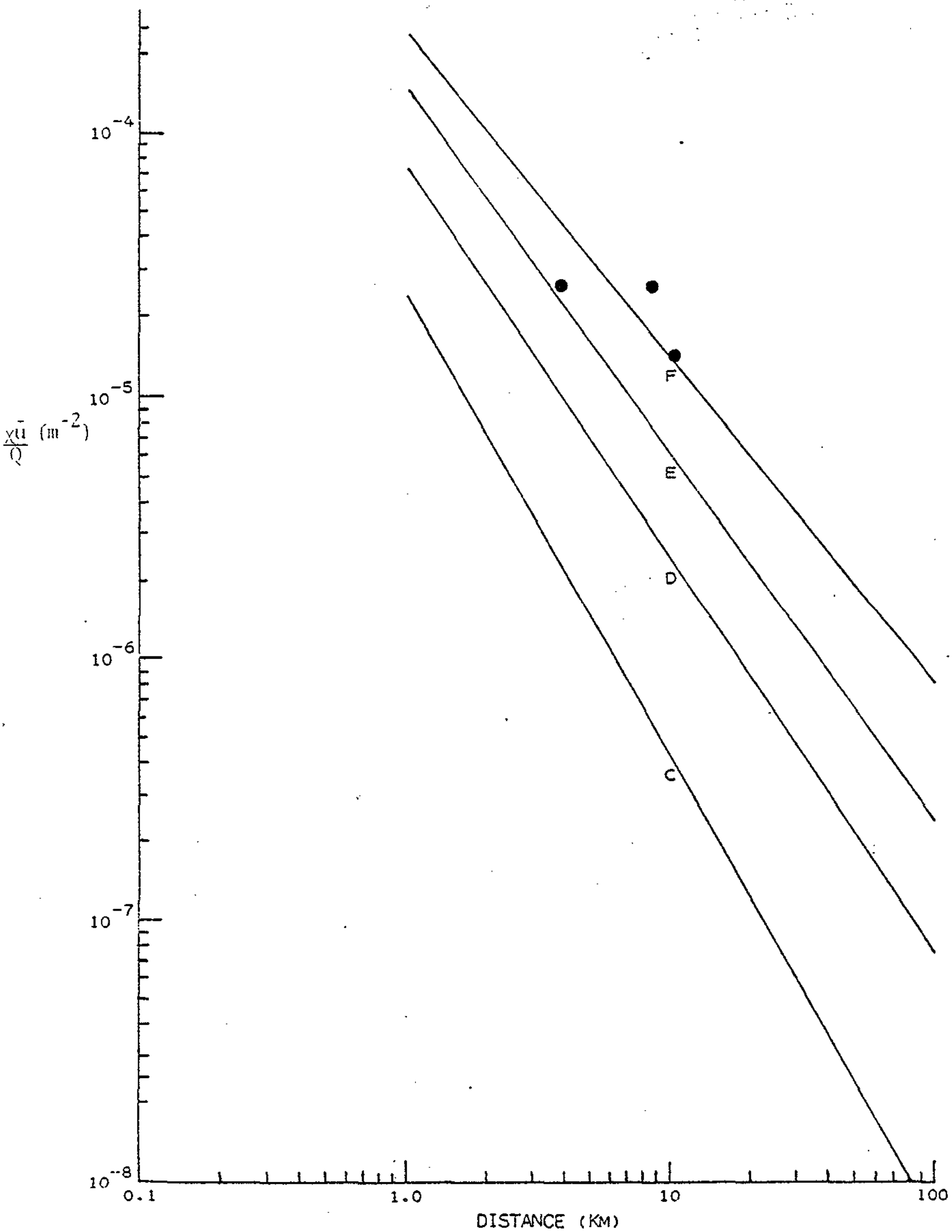


Figure 4.12-17 Measured values of $\frac{\chi \bar{u}}{Q}$ for Test 12.

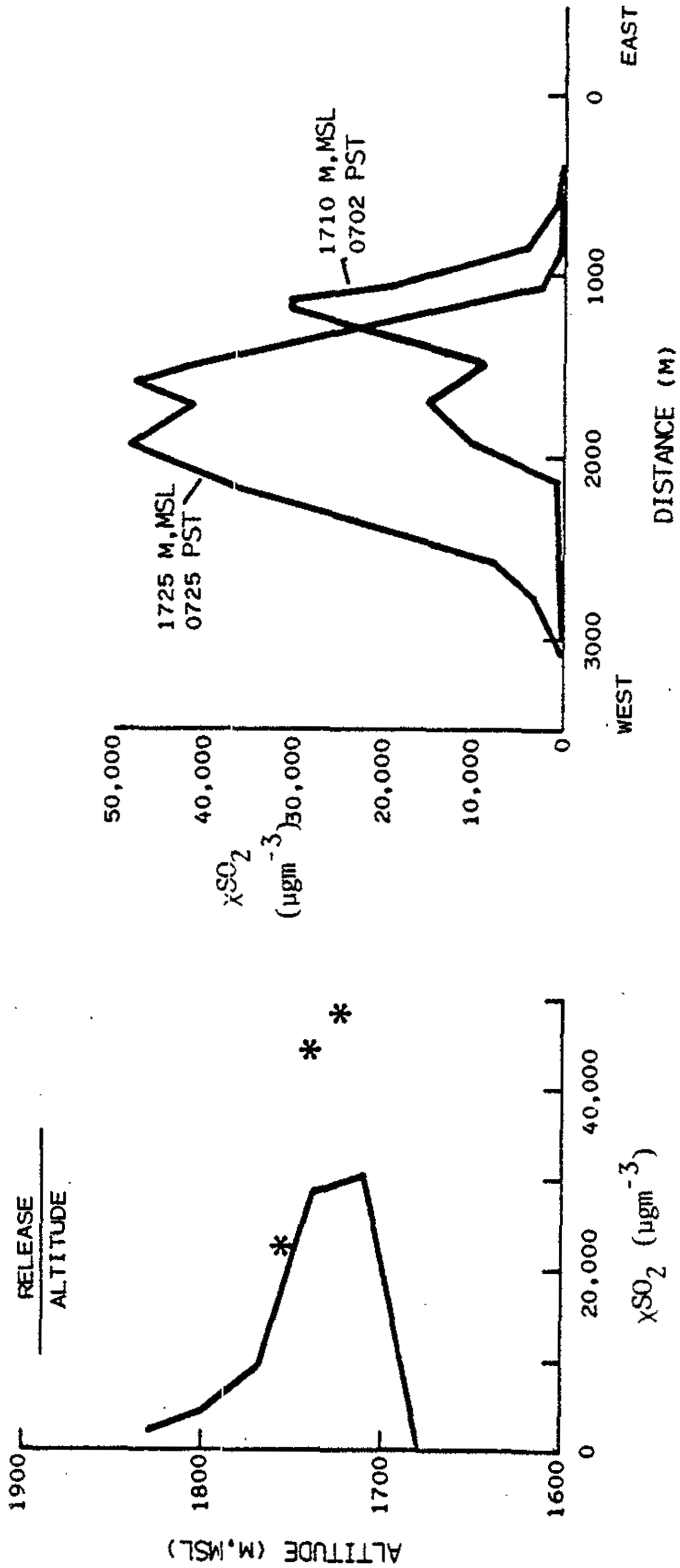


Figure 4.12-18 Vertical and horizontal plume centerline distributions, Test 12, Set 2.

the first set of crosswinds, both appear to indicate increasingly stable plume geometry.

The value of $\frac{X\bar{u}}{Q}$ (Figure 4.12-17) shows very little change as the maximum concentrations measured here were very close to those found during Set 1.

Further oil-fog data come from incidental measurements made during soundings and turbulence transects. These data have been used to construct a plot of centerline altitude and temperature vs. time during plume transport and dispersion. This figure, 4.12-19, shows the steady decrease in altitude and corresponding adiabatic increase in temperature as the plume was transported first to the south and then westward across the valley. The total drop in centerline altitude between 0545 and 0830 PST was approximately 365 m.

A maximum concentration of 27,676 μgm^{-3} was found near Anderson Creek at 0835 PST at an altitude of 1495 m MSL. This measurement was used to compute a minimum value of the normalized concentration at this point. This value is plotted in Figure 4.12-17. A centerline dilution rate no greater than that associated with F stability is indicated.

4.12.6 Aerial SF_6 Measurements. Aerial sampling of SF_6 consisted of the ten samples taken in two transects across the valley, as shown in Figure 4.12-20. Table 4.12-2 gives supplementary information. It can be seen that the first transect (samples 12H1-12H4), flown at an altitude of 1645 m MSL, between 0730 and 0738 PST, shows measurable SF_6 only in the westernmost samples, indicating that the plume had reached across the valley by 0738 PST and that equivalent concentrations of at least 3800 μgm^{-3} could be found approximately 150 m below release altitude over the center of the valley. The second transect (samples 5-8),

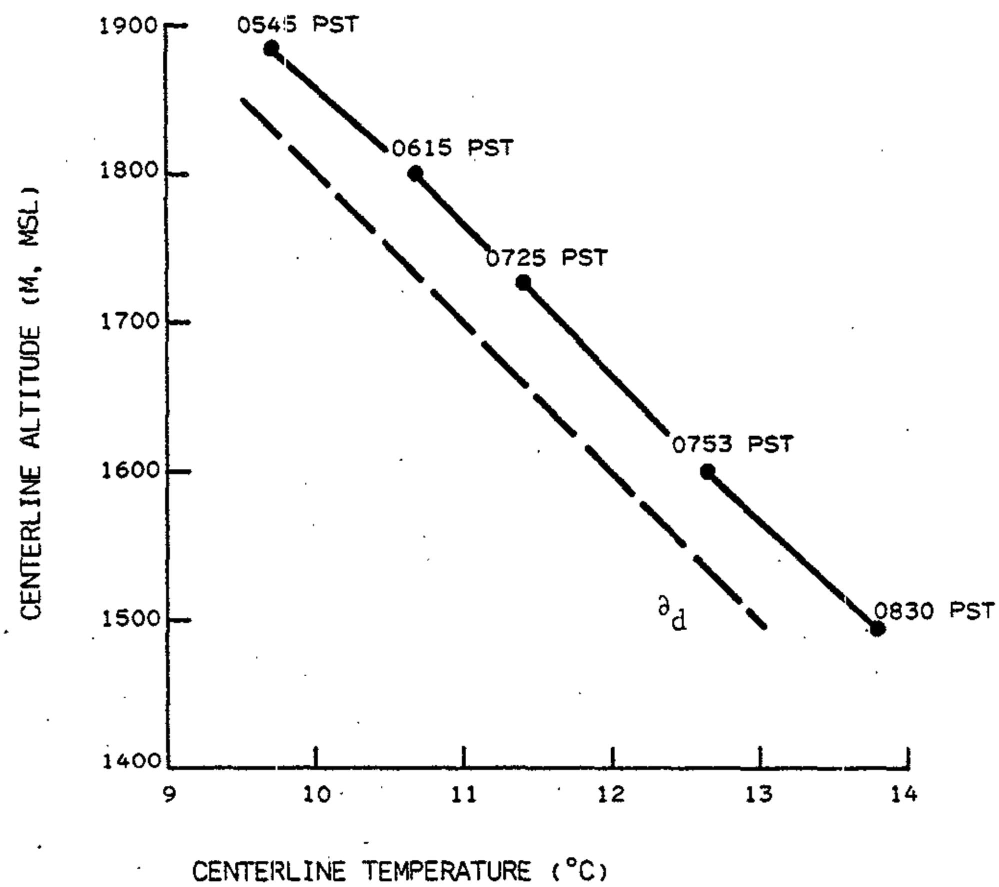


Figure 4.12-19 Plume centerline temperature vs. centerline altitude. Times of measurements are shown.

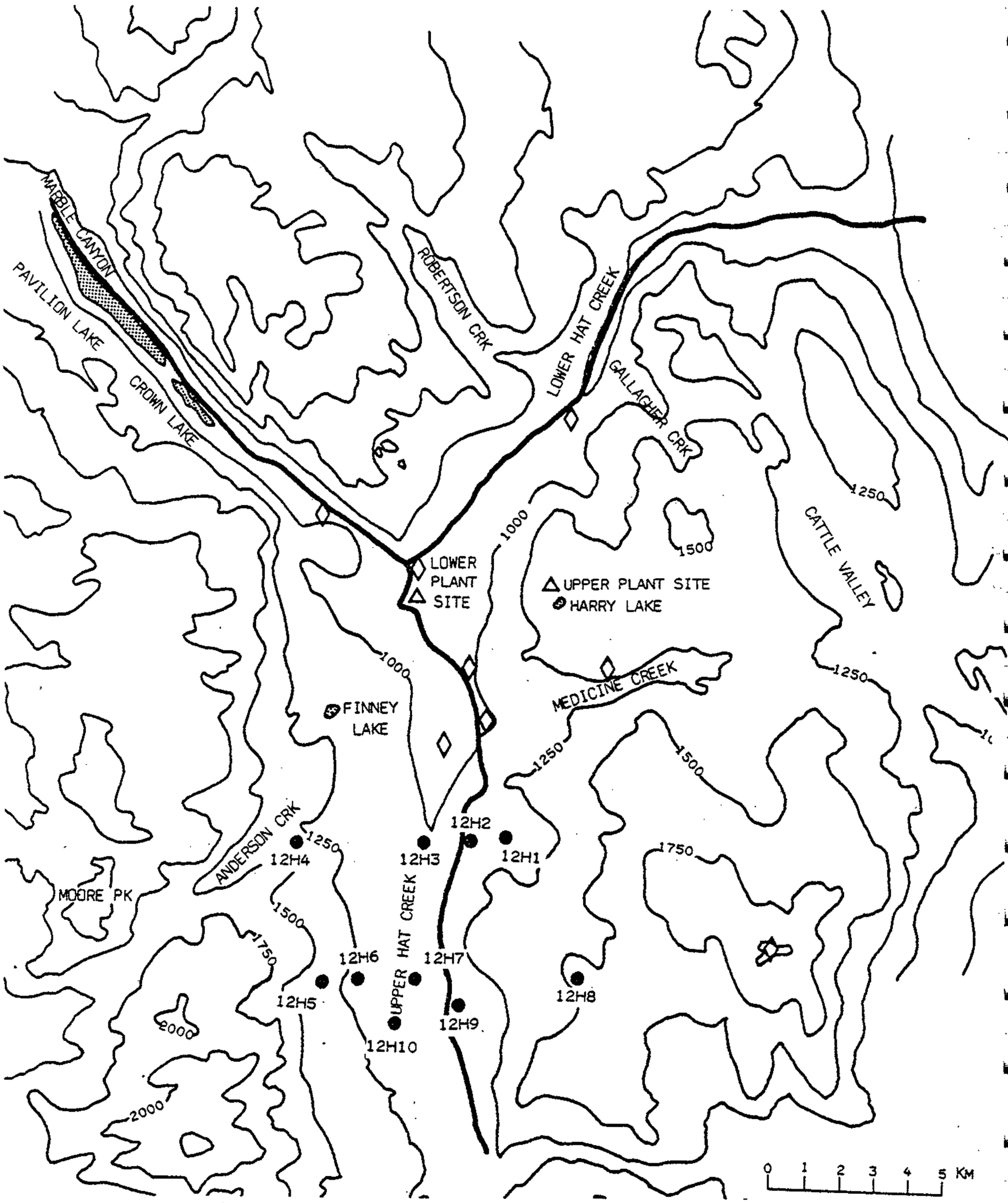


Figure 4.12-20 Location of aerial SF_6 samples, Test 12.

Table 4.12-2 Aerial SF_6 sample information.

Sample Number	Distance from Release (km)	Altitude (m) MSL	Altitude (m) AGL	Time (PST)	Sample Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
12H1	7.8	1645	550	0730	1	0	0
12H2	8.0	1645	640	0732	1	0	0
12H3	8.6	1645	208	0735	1	3798	4596
12H4	10.5	1645	365	0737	1	474	574
12H5	13.1	1525	185	0739	1	0	0
12H6	12.7	1525	305	0743	1	0	0
12H7	11.8	1525	490	0747	1	<20	<24
12H8	11.5	1525	SFC	0750	1	<20	<24
12H9	12.7	1370	230	0804	1	0	0
12H10	13.1	1370	215	0805	1	0	0

made further up the valley, shows only a very low concentration (< 20 μgm^{-3}) at 1525 m MSL over the center of the valley and at the surface of the eastern slopes.

4.12.7 Surface SF_6 Measurements. A total of 26 SF_6 sampler locations was employed during this long duration test. A map of their locations is given in Figure 4.12-21. Supplementary information is supplied in Table 4.12-3. The maximum measured ground level concentrations during Test 12 were equivalent to 7142 μgm^{-3} for 1 minute grab sample, 1014 μgm^{-3} for a half-hour average, and 534 μgm^{-3} one-hour average.

Samplers were initially deployed along the eastern slopes of the valley, as the plume moved south. Of these samplers (12S1-12S6) only one measured more than a near threshold amount of SF_6. This was site 12S2 at 1375 m MSL, near Ambusten Creek, which received an equivalent half-hour concentration of 38 μgm^{-3}. Samplers

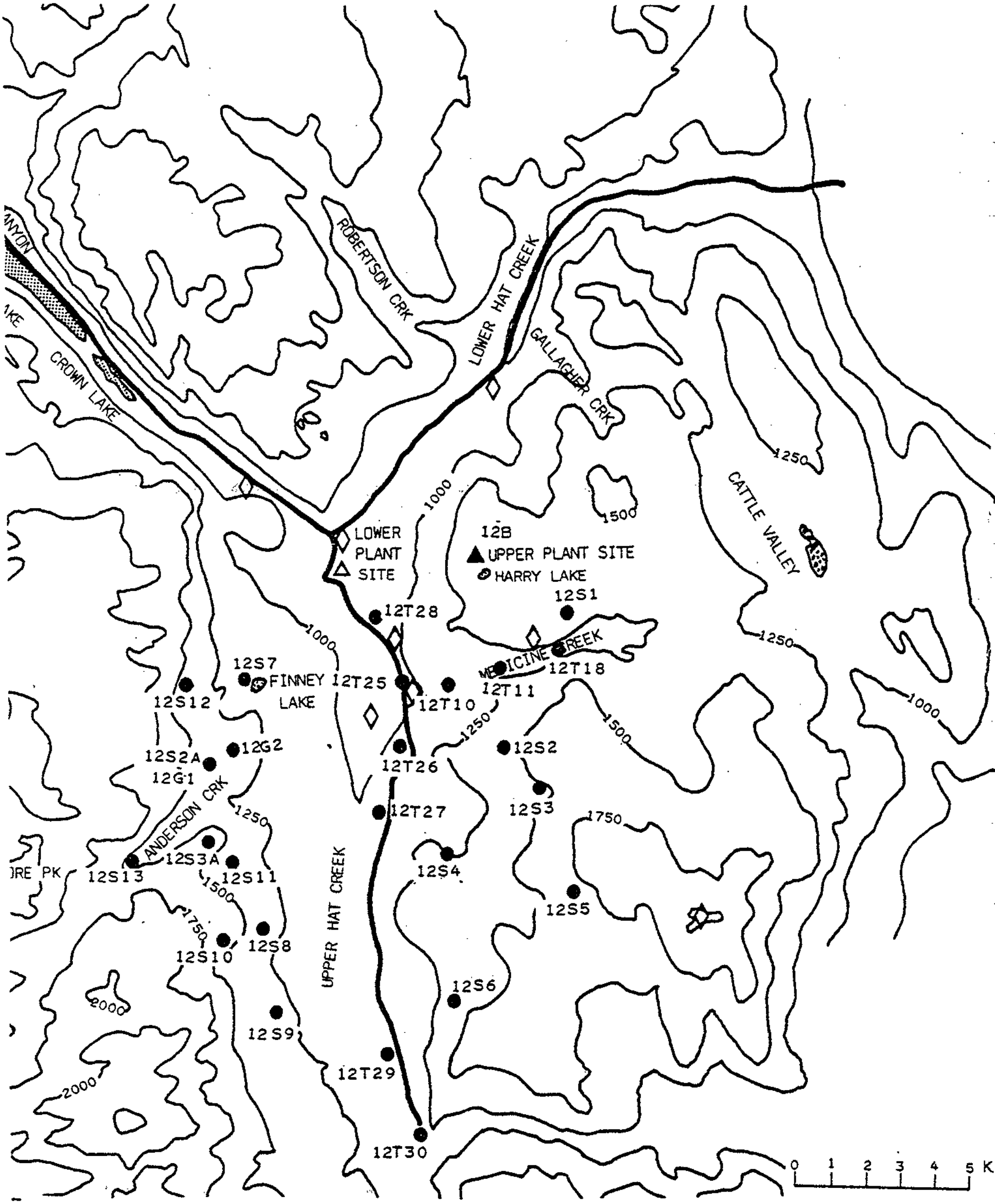


Figure 4.12-21 Location of surface SF_6 samplers, Test 12.

Table 4.12-3 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
12S1	2.7	1390	0534	0604	30	Malf.	0
			0604	0634	30	0	0
			0634	0704	30	0	0
			0704	0734	30	0	0
			0734	0804	30	0	0
			0804	0834	30	<20	<24
12S2	5.9	1375	0606	0636	30	38	46
			0636	0706	30	<20	<24
			0706	0736	30	<28	<34
			0736	0806	30	Malf.	-
			0806	0826	20	0	0
12S2A	9.7	1340	0839	0909	30	866	1048
			0909	0939	39	<20	<24
			0939	1009	30	<20	<24
			1009	1039	30	<20	<24
			1039	1109	30	<20	<24
			1109	1139	30	38	46
12S3	7.0	1495	0610	0640	30	Malf.	-
			0640	0710	30	0	0
			0710	0740	30	0	0
			0740	0810	30	0	0
			0810	0840	30	Malf.	-
12S3A	11.4	1600	0835	0905	30	1014	1227
			0905	0935	30	54	65
			0935	1005	30	120	145
			1005	1035	30	54	65
			1035	1105	30	38	46
			1105	1135	30	34	41
12S4	8.6	1250	0614	0721	67	0	0
			0721	0908	107	0	0
			0908	1108	120	0	0
12S5	9.9	1725	0619	0730	71	0	0
			0730	0905	95	0	0
			0905	1105	120	0	0

Table 4.12-3 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On (PST)	Time Off (PST)	Sampling Time (min)	XSO_2 (μgm^{-3}) Ambient	XSO_2 (μgm^{-3}) NTP
12S6	12.8	1525	0727	0900	93	0	0
			0900	1100	120	0	0
			0751	0821	30	0	0
			0821	0851	30	Malf.	-
			0851	0921	30	0	0
			0921	0951	30	0	0
			0951	1021	30	0	0
			1021	1051	30	Malf.	-
12S8	12.3	1390	0802	0832	30	Malf.	-
			0832	0902	30	Malf.	-
			0902	0932	30	0	0
			0932	1002	30	0	0
			1002	1032	30	0	0
			1032	1102	30	<20	<24
12S9	14.4	1375	0812	0842	30	1014	1227
			0842	0912	30	<20	<24
			0812	0942	30	42	51
			0942	1012	30	<20	<24
			1012	1042	30	38	46
			1042	1112	30	<20	<24
12S10	13.3	1555	0817	0856	39	474	574
			0856	1056	120	0	0
12S11	11.7	1375	0850	1050	120	0	0
12T10	3.8	1050	0525	0620	55	0	0
			0620	0705	45	0	0
			0705	0800	55	Malf.	-
12T11	3.2	1220	0543	0625	42	0	0
			0635	0715	50	Malf.	-
			0715	0825	70	0	0
12T18	3.2	1220	0630	0730	60	0	0
12T25	2.8	924	0600	0640	40	0	0
			0640	0740	60	0	0
			0740	0815	35	0	0
			0830	0920	50	0	0

Table 4.12-3 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
12T26	6.6	960	0610	0645	35	0	0
			0645	0745	60	0	0
12T27	8.6	1035	0615	0650	35	0	0
12T28	3.9	915	0700	0830	90	0	0
			0830	0925	55	0	0
12T29	14.6	1100	0755	0835	40	0	0
12T30	16.4	1115	0805	0840	35	0	0
12S12	9.5	1405	0840	0940	60	0	0
12S13	14.2	1495	0840	0940	60	516	624
12G1	9.7	1340	0845	0846	1	2808	3398
			0847	0848	1	7142	8642
			0852	0853	1	2312	2798
12G2	7.5	1405	0850	0851	1	764	924
12B	0.0	1370	0600	0700	60	0	0
			0700	0800	60	0	0
			0800	0900	60	0	0

deployed at the plant site, up Medicine Creek, and along Upper Hat Creek recorded no measurable impact during the test.

Once it was clear that the plume was moving westward across the valley, samplers were quickly placed along the western slopes where fumigation appeared likely. Samplers 12S2A, 12S3A, 12S9, 12S10, 12S13, and the grab samples taken at 12G1 (12S2A), and 12G2 all yielded measurable SF_6. Sequential samplers 12S2A, 12S3A, and 12S9 showed common fumigation patterns of initially high half-hour concentrations (866-1014 μgm^{-3}), rapidly diminishing to 20-60 μgm^{-3}, and continuing low concentrations through the morning. Site 12S10 received 474 μgm^{-3} in a 39-minute sample from 0817-0856 PST, and 12S13 received 516 μgm^{-3} in a one-hour sample from 0850-0940 PST. The maximum measured concentration was found to be 7142 μgm^{-3} in a one-minute grab sample (12G1) taken at site 12S2A at 0845 PST. The data suggest that the maximum concentrations occurred on the ridgecrests between creek systems draining the western hills.

The fact that samples from sites 12S8, 12S7, 12S12, and 12S11 received no measurable SF_6 is believed to be indicative of the localized nature of the fumigation patterns, and suggests that the mixed portions of the plume were transported up the slopes towards the west and did not re-enter the valley circulation in detectable concentrations.

4.12.8 Turbulence Measurements. Turbulence data from Test 12 are plotted in Figure 4.12-22. Data are available both from the oil-fog crosswind patterns and from special turbulence transects.

The data from the crosswind patterns suggest very light turbulence and little intermittence during Sets 1 and 2 with some increase in both parameters during Set 2 above 1770 m MSL.

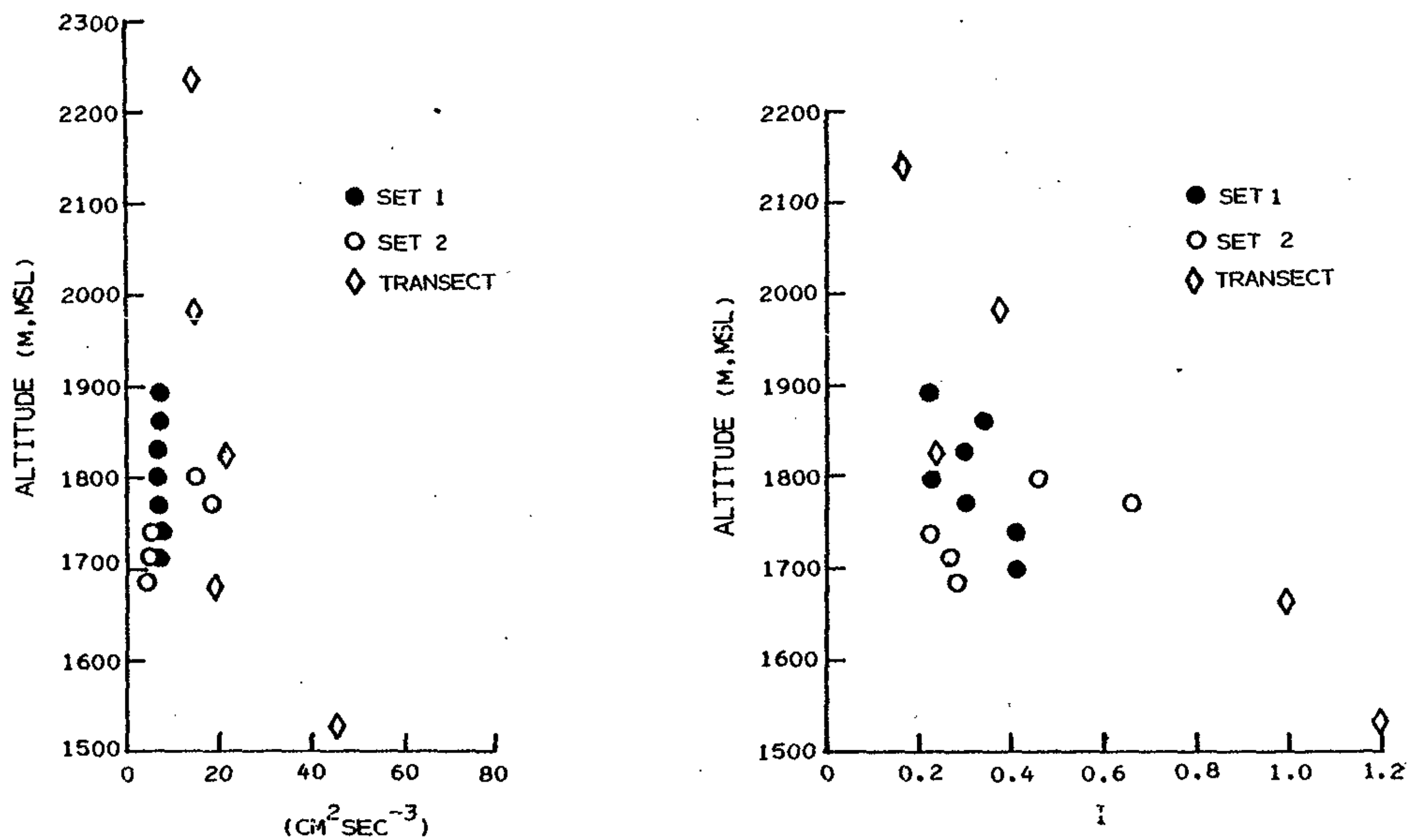


Figure 4.12-22 Turbulence measurements vs. altitude, Test 12.

The turbulence transects were made as shown in Figure 4.12-14 along the western slopes of Hat Creek Valley between 0806 and 0832 PST. These data indicate light turbulence between 2135 and 1680 m MSL increasing to values associated with neutral dispersion at 1530 m. Intermittence values were rather low between 2135 and 1830 m MSL, then increased to high values at 1675 and 1525 m MSL.

These measurements suggest that the major source of turbulence was surface heating and that at the time of the transects, some thermal disturbances were reaching as high as 1675 m but not as high as 1800 m MSL.

4.12.9 Summary of Test 12. The Test 12 tracer plume was released from the upper site at an altitude of 1890 m MSL. The meteorological conditions at release altitude were characterized by light northerly winds which gradually veered to the east. Lapse rates were near neutral at release altitude with a radiation inversion below. The inversion was gradually dissipated during the test. On the surface, a well-developed valley circulation was evident. Upon release, the very stable appearing plume moved southward over the west-facing slopes which bound the east side of Upper Hat Creek. It was then transported westward across the valley, apparently in response to local surface heating, and fumigated. Oil-fog tracking data indicate the plume sank consistently during the test (390 m in the first 165 minutes). This was also apparently in response to the heating and represents the vertical component of the cross-valley circulation.

Surface SF_6 data show maximum half-hour and one-hour concentrations of respectively 1014 and 534 μgm^{-3} during fumigation. The area where significant surface concentrations were found was limited to the slopes of the valley, from Finney Lake south to Parke Lake.

Aerial oil-fog data indicate rather stable plume geometry prior to fumigation, and show a centerline dilution rate nominal for F type stability. Measurements of turbulence dissipation rates show low, stable atmosphere values initially. Later, measurements over the western slopes showed continued low values aloft but near neutral rates closer to the surface.

In summary, this test represents a special case of valley fumigation characterized by:

a) An early morning light northeasterly (up-valley) gradient flow, with a near neutral lapse rate at plume altitude, and a shallow surface inversion. As a consequence of the light wind conditions, both near the surface and aloft, and the damping effect of the surface inversion on convection activity, dispersion conditions at plume altitude remained very stable.

b) A cross-valley transport of the plume in response to the relatively more rapid solar heating of the east-facing slopes. This effect was combined with substantial sinking of the plume layer due to the cross-valley differences in potential temperature.

c) Eventual fumigation when heating destroyed the stable layer over the western slopes.

4.13 Test Number Thirteen, August 10, 1976

Test 13 was carried out at the upper plant site during the early afternoon of August 10, 1976. An assumed stack height of 183 m, combined with 366 m plume rise, gave a tracer release altitude of 1920 m MSL. The meteorological conditions, characterized by light winds and strong insolation, were conducive to studying looping plume behavior.

4.13.1 <u>Synoptic Setting for Test 13</u>. High pressure remained over the project area. During the day, the ridge of high pressure, located over southwestern British Columbia in the morning, moved eastward and was east of the project area by evening. As a result, the low-level gradient wind veered from northerly in the morning to east-southeasterly in the afternoon. Small cumuli developed first over the hills during mid-morning and were scattered throughout the project area during the test.

Surface and 700-mb maps are shown in Figure 4.12-1, in the previous section.

4.13.2 <u>Meteorological Parameters for Test 13</u>. Parameters measured during this test include lapse rates, surface winds, and winds aloft. Temperature soundings were taken by the NAWC tracer aircraft and double-tracked minisonde. Surface winds were monitored by the B. C. Hydro wind station network. Double-tracked pilot balloon ascents were used to obtain winds aloft data.

The temperature soundings from Test 13 are presented in Figure 4.13-1. Both an 1134 PST sounding taken at the lower site and the 1210 PST upper site minisonde reveal neutral conditions extending from the surface through plume altitude to 2100 m MSL. The minisonde data show a slight increase in stability at 2400 m MSL. Although this is not evident in the data, super-adiabatic conditions probably existed near the surface.

Surface wind data for this test may be found in Volume 2, Field Data. It can be seen that surface winds during the test were generally up-valley at less than 2.5 m/s. The data from weather station 5, however, indicate light to moderate southerly flow during this period, suggesting the development of a cellular circulation within the valley.

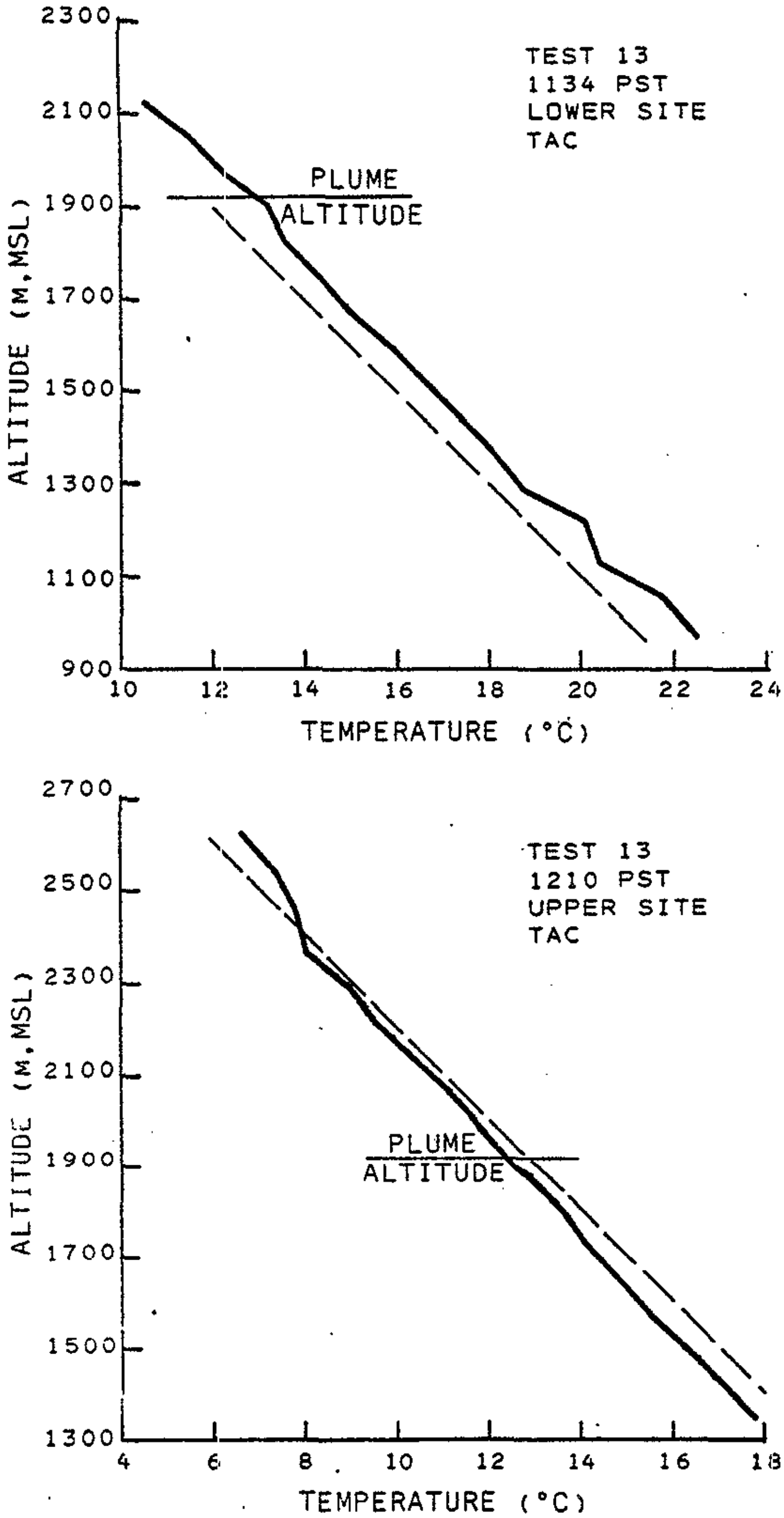


Figure 4.13-1 Vertical temperature profiles measured during Test 13.

The winds aloft time sections of wind direction and wind speed are presented in Figures 4.13-2 and 4.13-3, respectively. These show that winds at plume altitude were from the east to southeast at 1-2 m/s during tracer dissemination. Winds became more easterly, at up to 3 m/s, following the release.

4.13.3 <u>Tracer Dissemination, Test 13</u>. The pertinent tracer release parameters for this test are given in Table 4.13-1, below.

Table 4.13-1 Duration and source strength of tracer release number 13.

Location: Upper Site
Altitude: 1920 m MSL
Simulated Stack Height: 183 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	1140	1240	18,955	5.27
Oil Fog (1)	1140	1214	109,800	52.2
Oil Fog (2)	1233	1240	N/A	N/A

4.13.4 <u>Visual and Photographic Observations</u>. As with the other looping plume release (Test 9), plume transport was initially more vertical than horizontal. Figure 4.13-4 shows considerable downward mixing near the release site at 1154 PST. Another view of the plume at 1215 PST (Figure 4.13-5) shows that the smoke just released was descending, while the leading edge of the plume was being swept up in an updraft. This looping behavior continued throughout the test. The determination of forward plume speed was very difficult due to the transient nature of the loops. However, the horizontal movement has been estimated at about 1 m/s. The approximate plume outlines are shown in Figure 4.13-6.

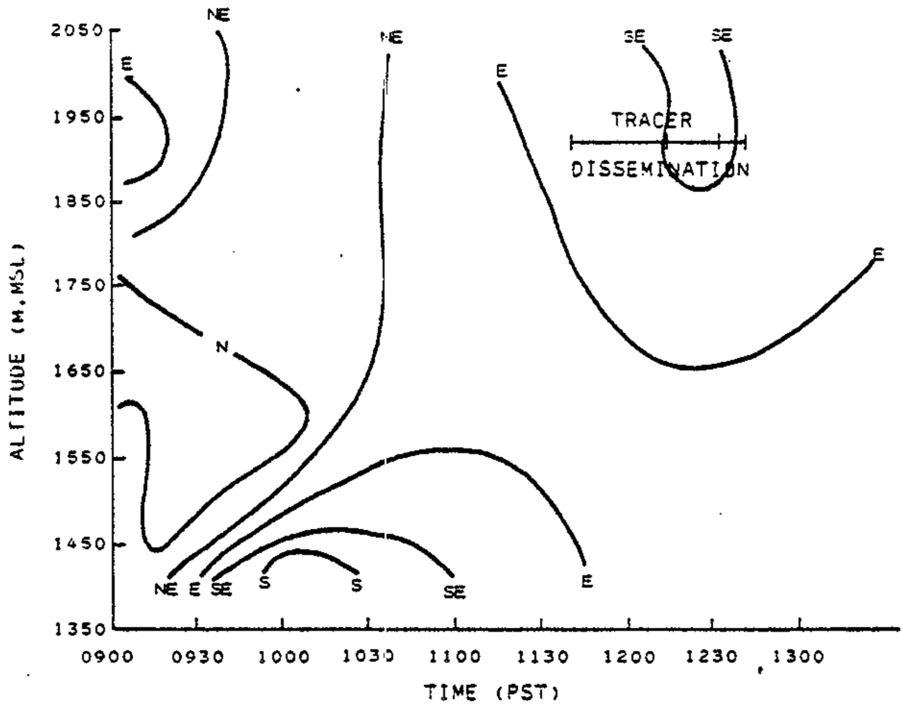


Figure 4.13-2 Time vs. altitude display of wind directions aloft measured during Test 13. Speeds are given in m/s.

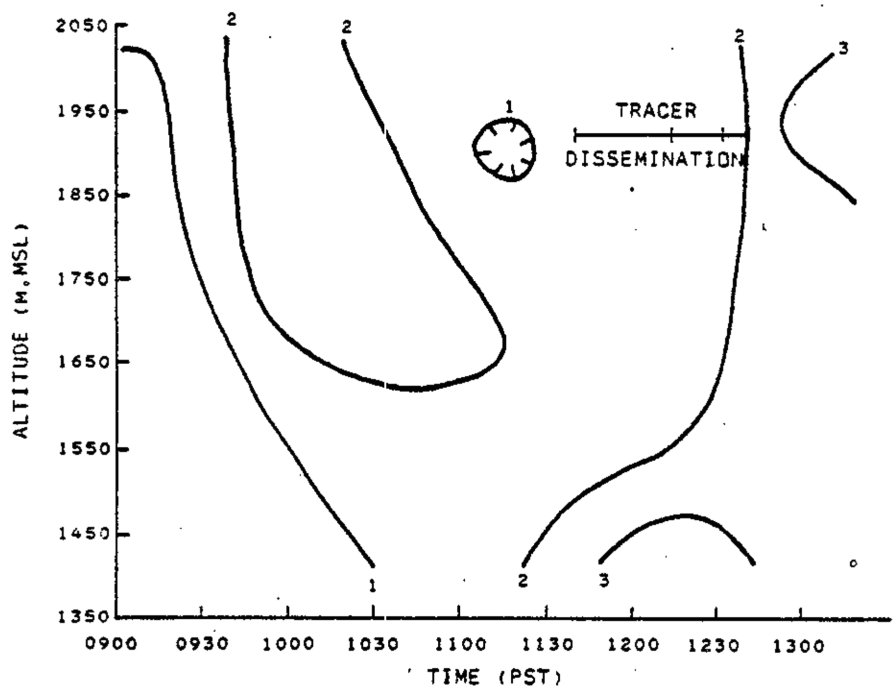


Figure 4.13-3 Time vs. altitude display of wind speeds aloft measured during Test 13. Speeds are given in m/s.

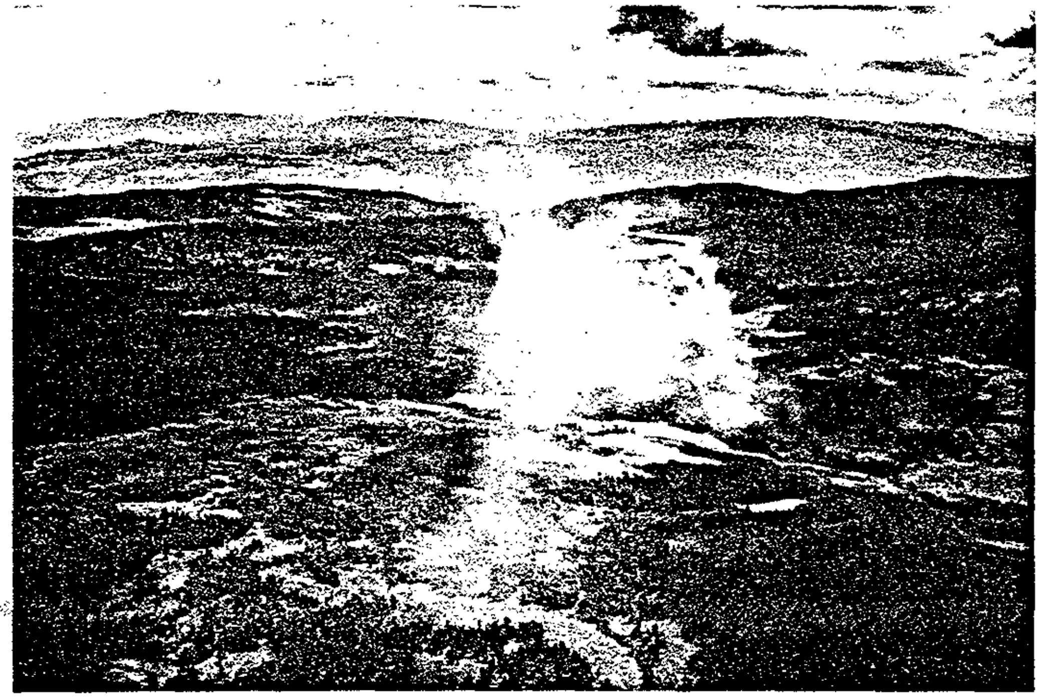


Figure 4.13-4 Photo, Test 13. This view towards the southeast shows the plume being transported rapidly towards the surface under the influence of a strong downdraft. Time is 1154 PST.

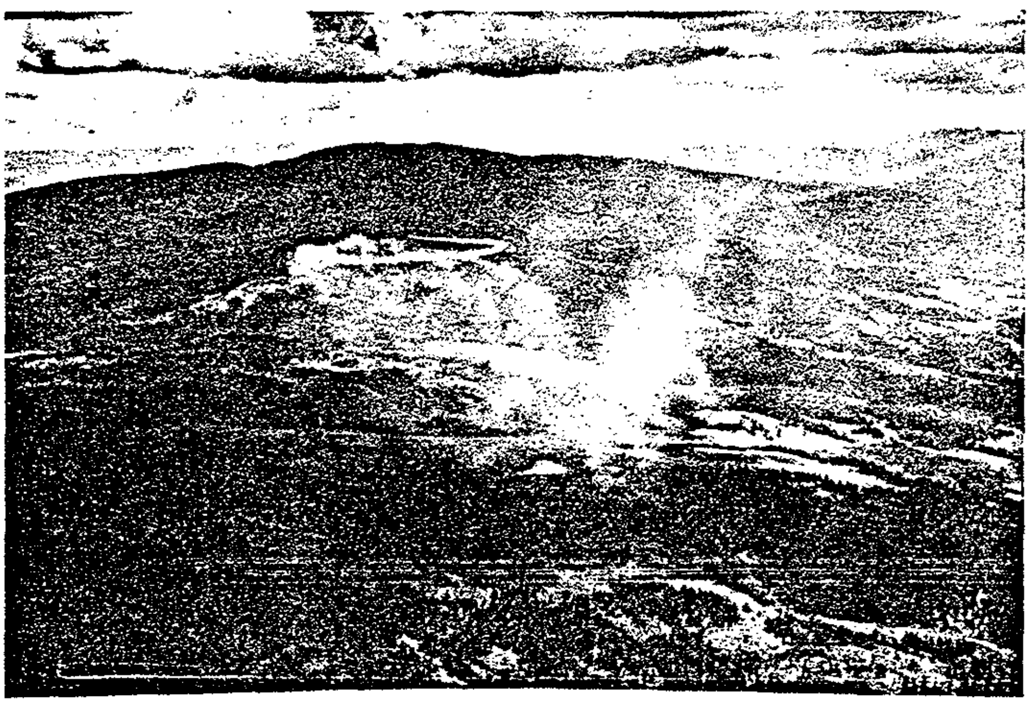


Figure 4.13-5 Photo, Test 13. The leading edge of the looping plume is ascending in an updraft while the portion just released is descending in this view towards the south. Picture taken at 1215 PST.

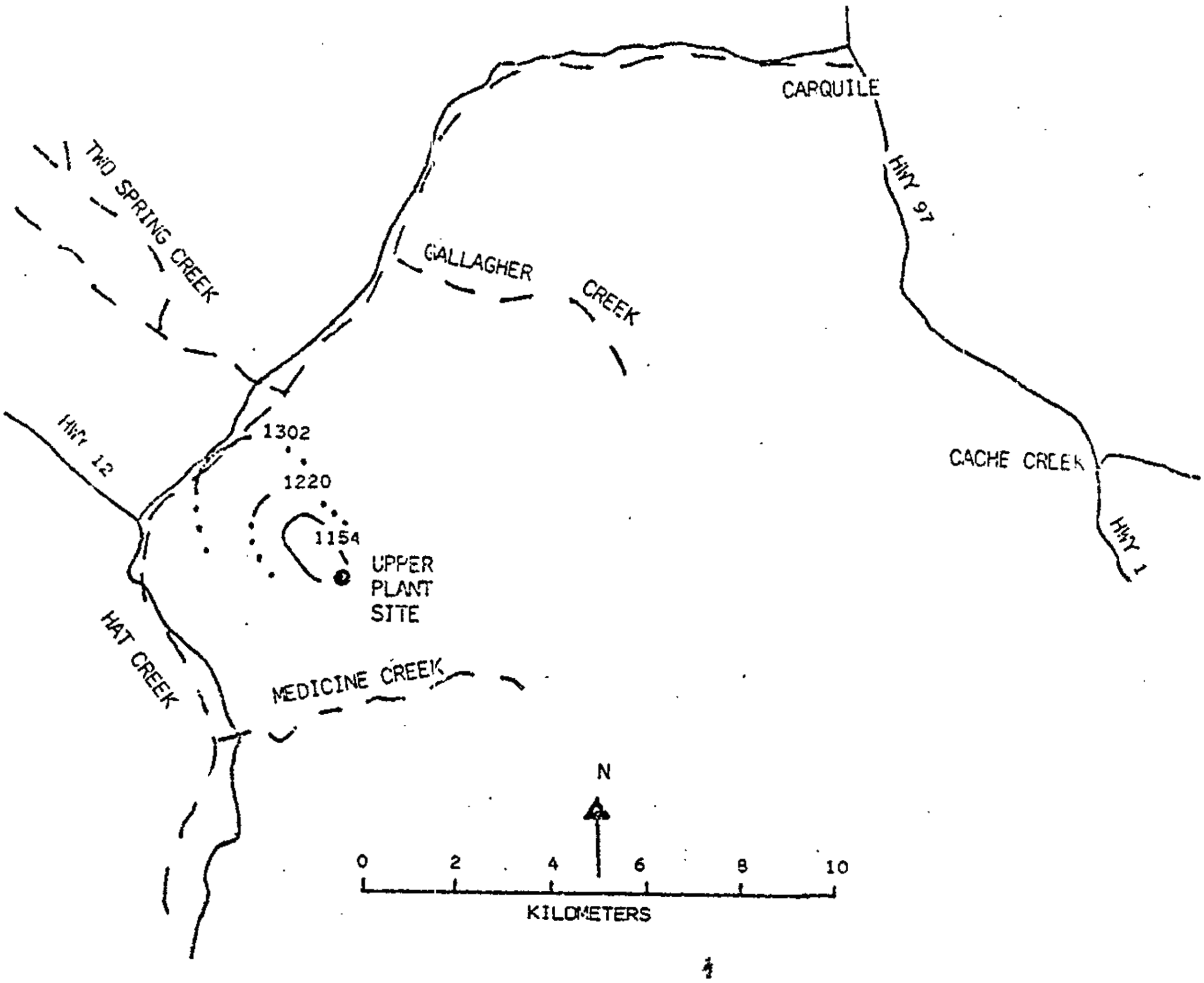


Figure 4.13-6 Approximate plume outlines at various times during Test 13.

4.13.5 Aerial Oil-Fog Measurements. Aerial oil-fog measurements from Test 13 were gathered during a set of crosswind patterns flown 1.6 km downwind over the slopes west of the upper plant site as shown in Figure 4.13-7. Thirteen passes were made at altitudes from 1100 to 1890 m MSL between 1206 and 1232 PST.

The plume centerline distributions are given in Figure 4.13-8. These indicate the high degree of vertical and horizontal spreading which this plume experienced quite close to the release. The maximum concentration measured, equivalent to 4581 μgm^{-3}, was found at 1405 m MSL (350 m AGL). This is 515 m below release altitude. Concentrations as high as 1832 μgm^{-3} were found within 50 m of the ground on the lowest pass.

An analysis of plume geometry shows a strong tilt to the centerline, with the maximum concentrations at the highest altitudes being found about 3 km north of where the maximum concentrations were found on the lowest passes. This would suggest that the plume first moved in a northwesterly direction and those portions which sank were swept southward with the low-level up-valley flow.

The values of σ_y and σ_z for these measurements appear in Figure 4.13-9. It can be seen that σ_y was quite large, indicating a very unstable atmosphere, while the value of σ_z was nominal for neutral conditions. The value of $\frac{X\bar{u}}{Q}$ appears in Figure 4.13-10 and suggests very rapid centerline dilution.

4.13.6 Aerial SF_6 Measurements. No aerial SF_6 measurements were made during this test as rapid movement of samplers required the use of both helicopters.

4.13.7 Surface SF_6 Measurements. The locations of the SF_6 samplers deployed for this test are shown in Figure 4.13-11, and additional information is supplied in Table 4.13-2. Thirteen

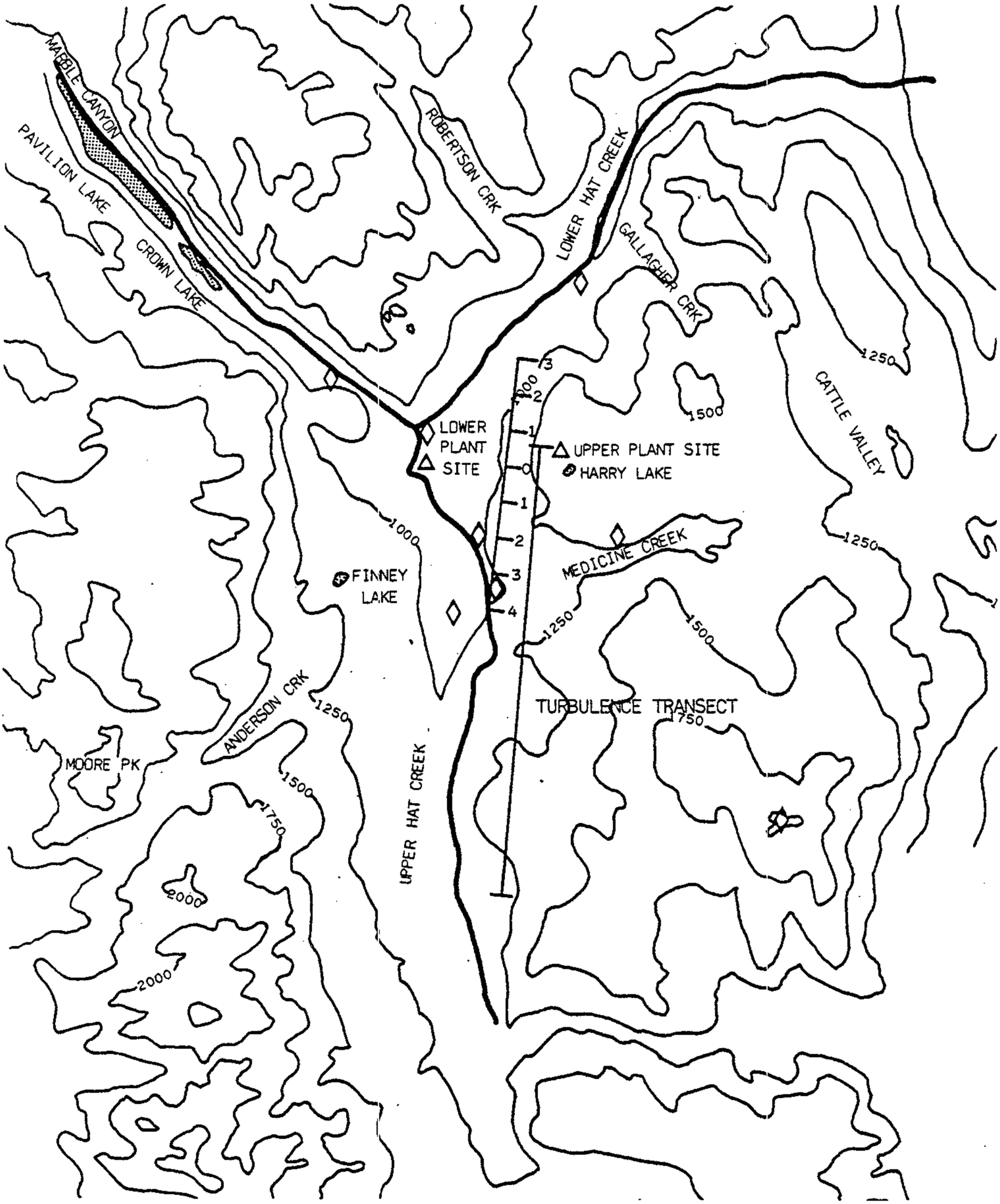
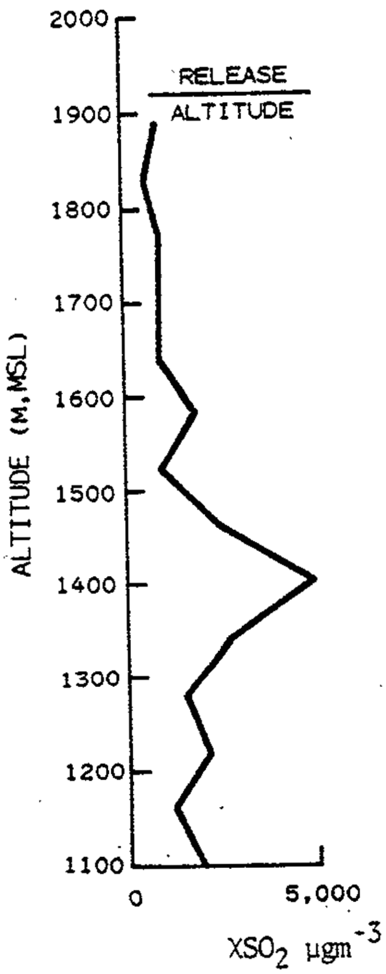


Figure 4.13-7 Location of oil-fog crosswind patterns and turbulence transects, Test 13. Distances are in kilometers.



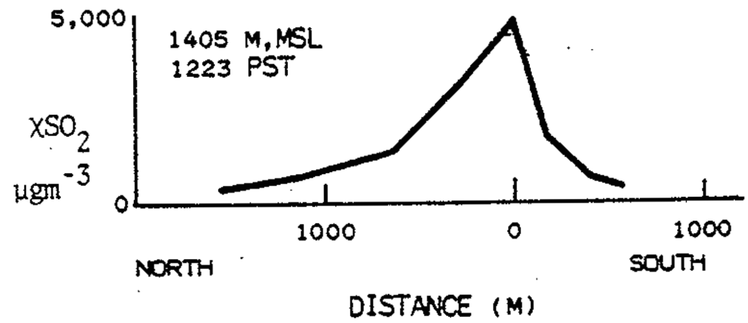


Figure 4.13-8 Horizontal and vertical plume centerline distributions for Test 13.

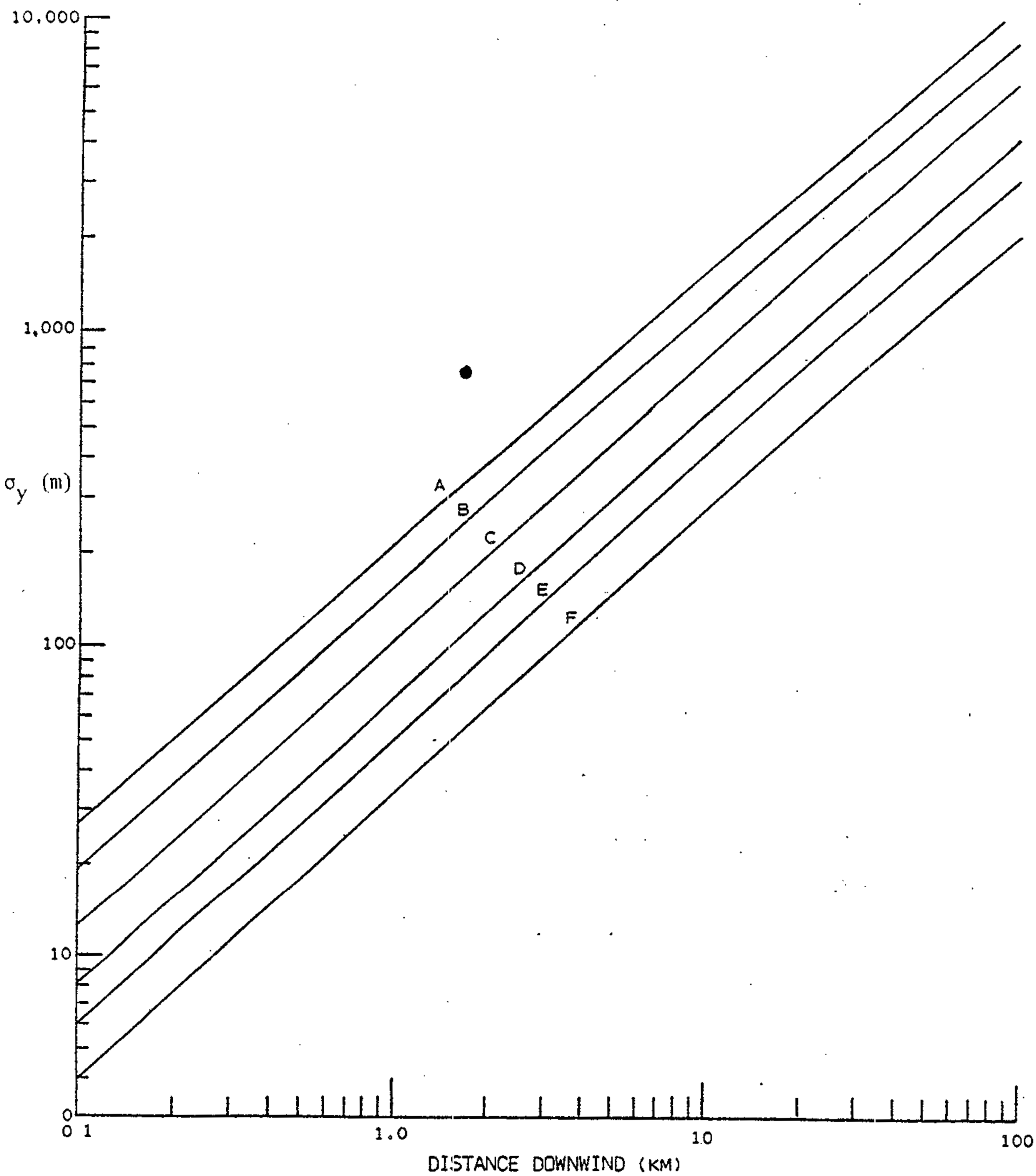


Figure 4.13-9 Measured values of σ_y and σ_z for Test 13.

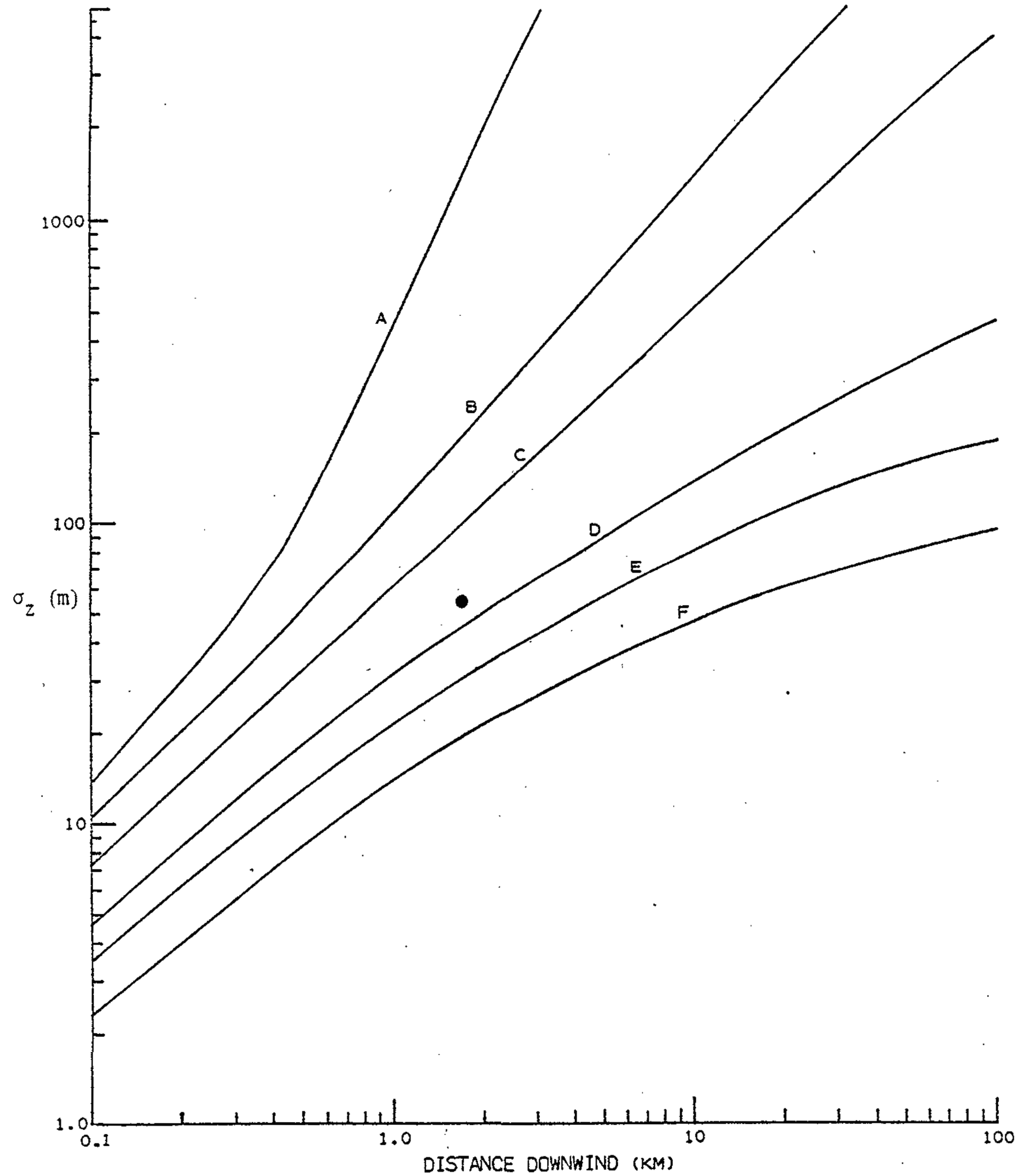


Figure 4.13-9 (Cont'd)

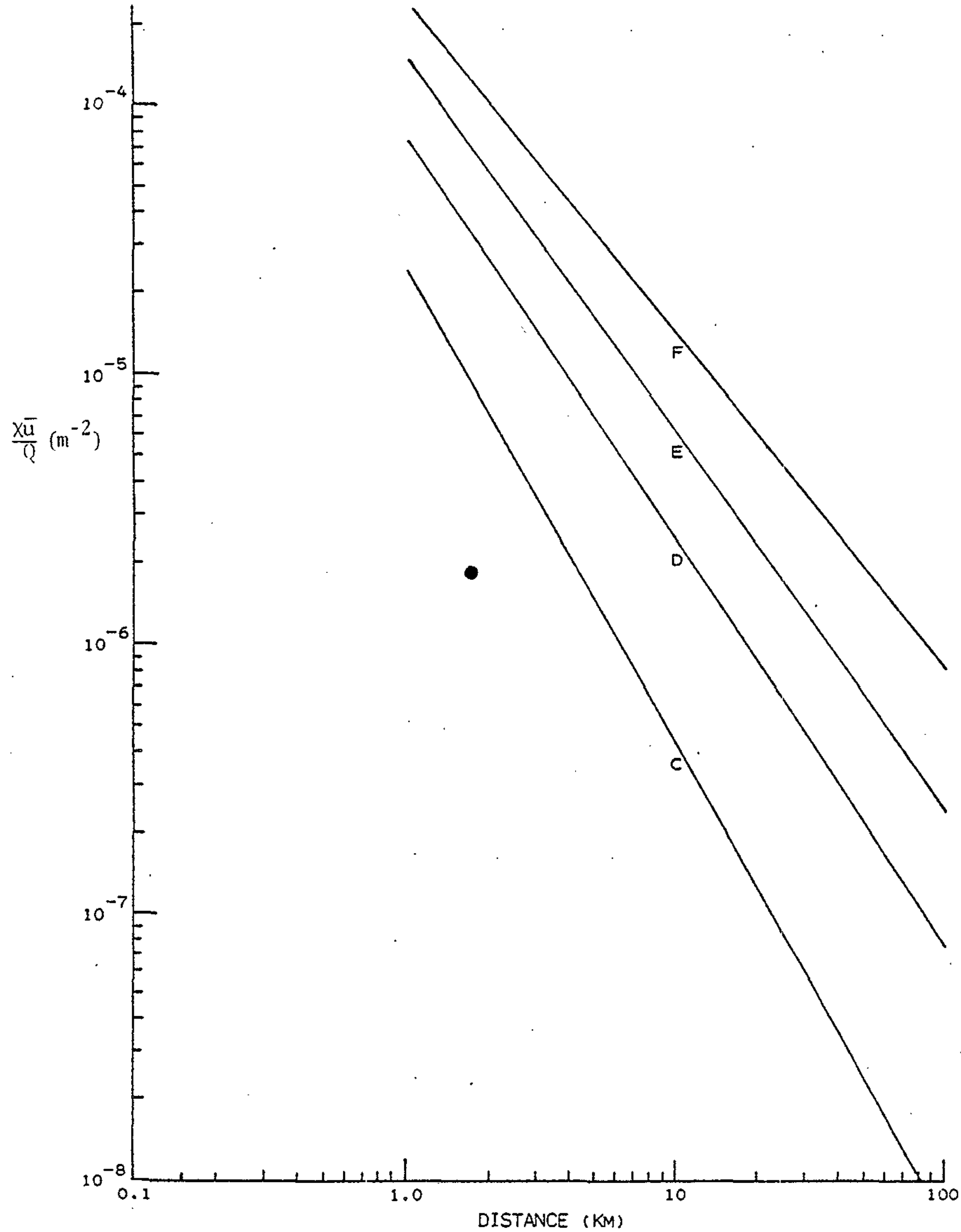


Figure 4.13-10 Measured values of $\frac{\chi \bar{u}}{Q}$ for Test 13.

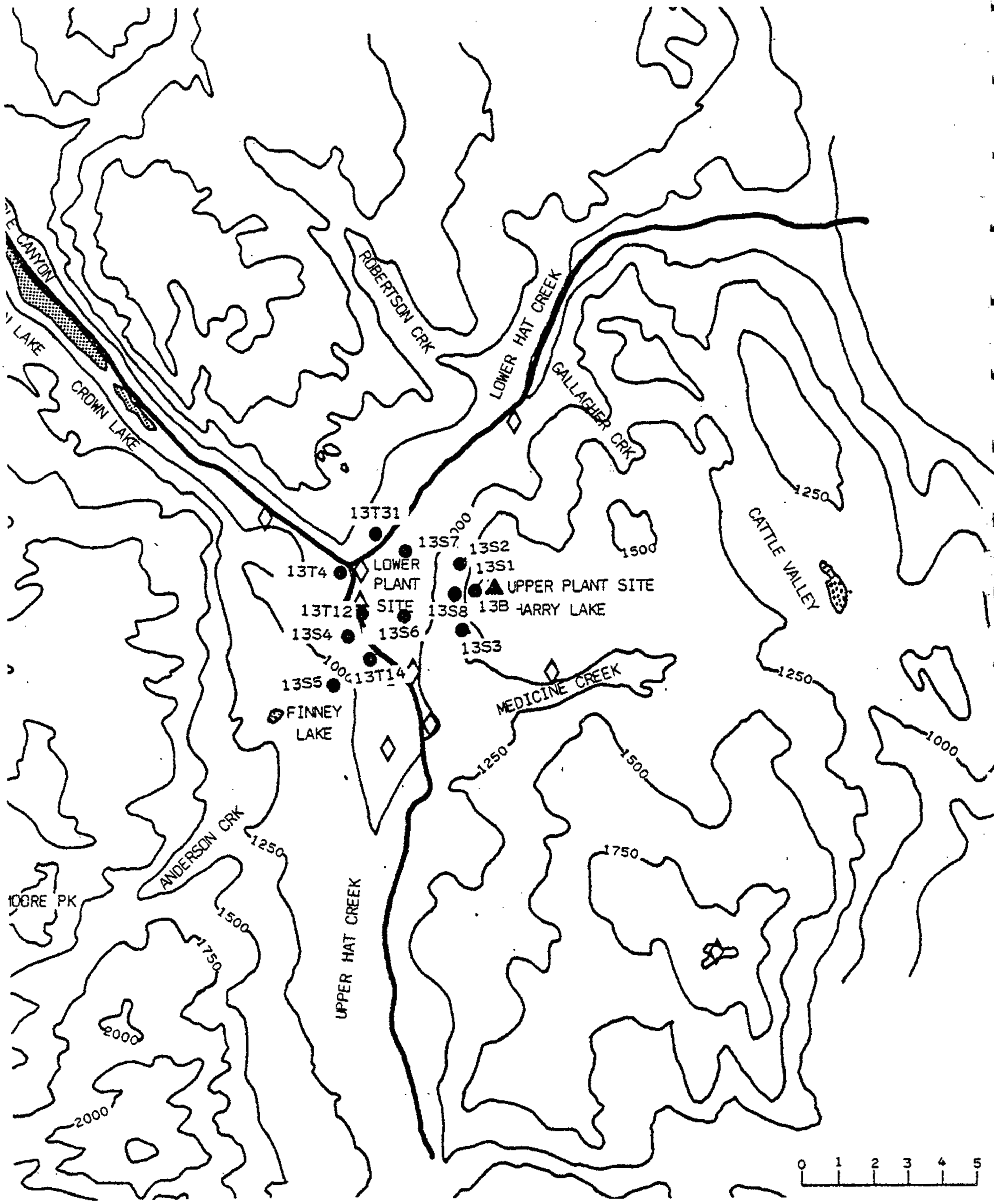


Figure 4.13-11 Location of surface SF_6 samplers, Test 13.

Table 4.13-2 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On (PST)	Time Off (PST)	Sampling Time (min)	XSO_2 (μgm^{-3}) Ambient	NTP
13S1	0.4	1340	1201	1246	45	1328	1621
			1256	1316	30	0	0
13S2	0.8	1130	1207	1237	30	1546	1888
			1237	1307	30	38	46
			1307	1347	40	416	508
13S3	1.6	1175	1213	1243	30	28	34
			1243	1313	30	Malf.	-
			1313	1321	7	Malf.	-
13S4	4.8	945	1219	1337	78	64	78
13S5	5.6	1035	1225	1255	30	<20	<24
			1255	1325	30	162	198
			1325	1342	17	32	39
13S6	3.5	945	1240	1327	47	300	366
13S7	3.0	900	1200	1244	44	48	57
			1244	1325	41	162	198
13S8	0.9	1220	1215	1218	3	1584	1934
			1220	1223	3	1110	1355
			1225	1228	3	<20	<24
			1230	1233	3	0	0
			1235	1238	3	0	0
			1240	1243	3	0	0
			1245	1248	3	0	0
13T4	4.4	840	1150	1210	20	0	0
			1210	1238	18	0	0
			1238	1302	24	Malf.	-
			1302	1330	28	344	420
13T12	4.3	855	1205	1224	19	0	0
			1224	1258	34	Malf.	-
			1258	1320	22	218	266
			1320	1330	10	162	198
13T14	4.3	885	1140	1200	20	0	0
			1200	1218	18	0	0
			1218	1252	34	84	103
			1252	1315	23	336	410
			1315	1325	10	118	144
13T31	3.9	840	1155	1213	18	Malf.	-
			1213	1245	32	44	54
			1245	1308	23	Malf.	-
			1308	1335	33	226	276
13B	0.0	1350	1200	1215	15	0	0
			1215	1230	15	0	0
			1230	1245	30	0	0
			1245	1300	30	0	0
			1300	1315	30	0	0

samplers were deployed southwest through northwest of the upper plant site. Each of these received tracer material in concentrations ranging up to about 1500 μgm^{-3}. The maximum short and long-term concentrations were found to have occurred early in the test, at sites located on the slopes just north and west of the plant site. These sites (13S1, 13S2, and 13S8) were all within 1 km of the site. The maximum concentration was found to be a three-minute average of 1584 μgm^{-3} at site 13S8. Maximum half-hour and hour values were found at sites 13S2 and 13S1, where concentrations were found to be 1546 and 996 μgm^{-3}, respectively. Other sites on the slopes measured maximum concentrations ranging from 28 to 300 μgm^{-3}. Interestingly, no SF_6 was found at the plant site, although concentrations as high as 1328 μgm^{-3} (half-hour average) were found within 400 meters.

All other samplers received SF_6 at some time during the test, with maximum concentrations ranging from 64 to 344 μgm^{-3}. Sampler 13S5, located 5.6 km from the release point, towards Finney Lake, received 162 μgm^{-3} in a 30-minute sample, while sites 13T14 near the drill camp, and 13T4 near Weather Station 2, received 336 and 344 μgm^{-3} in 23 and 28 minutes samples, respectively. The maximum one-hour concentration in the valley was at least 186 μgm^{-3} at site 13T14.

4.13.8 Turbulence Measurements. The turbulence measurements for this test were gathered during the oil-fog crosswind patterns and during turbulence transect patterns. The data are plotted in Figure 4.13-12. It can be seen that the measurements made during the oil-fog patterns indicate that turbulence was heavy near the ground and decreased gradually to moderate values at higher altitudes. Intermittence values were moderate and showed little change with altitude.

The turbulence transects were made in a north-south line along the east side of the valley extending from White Rock Creek

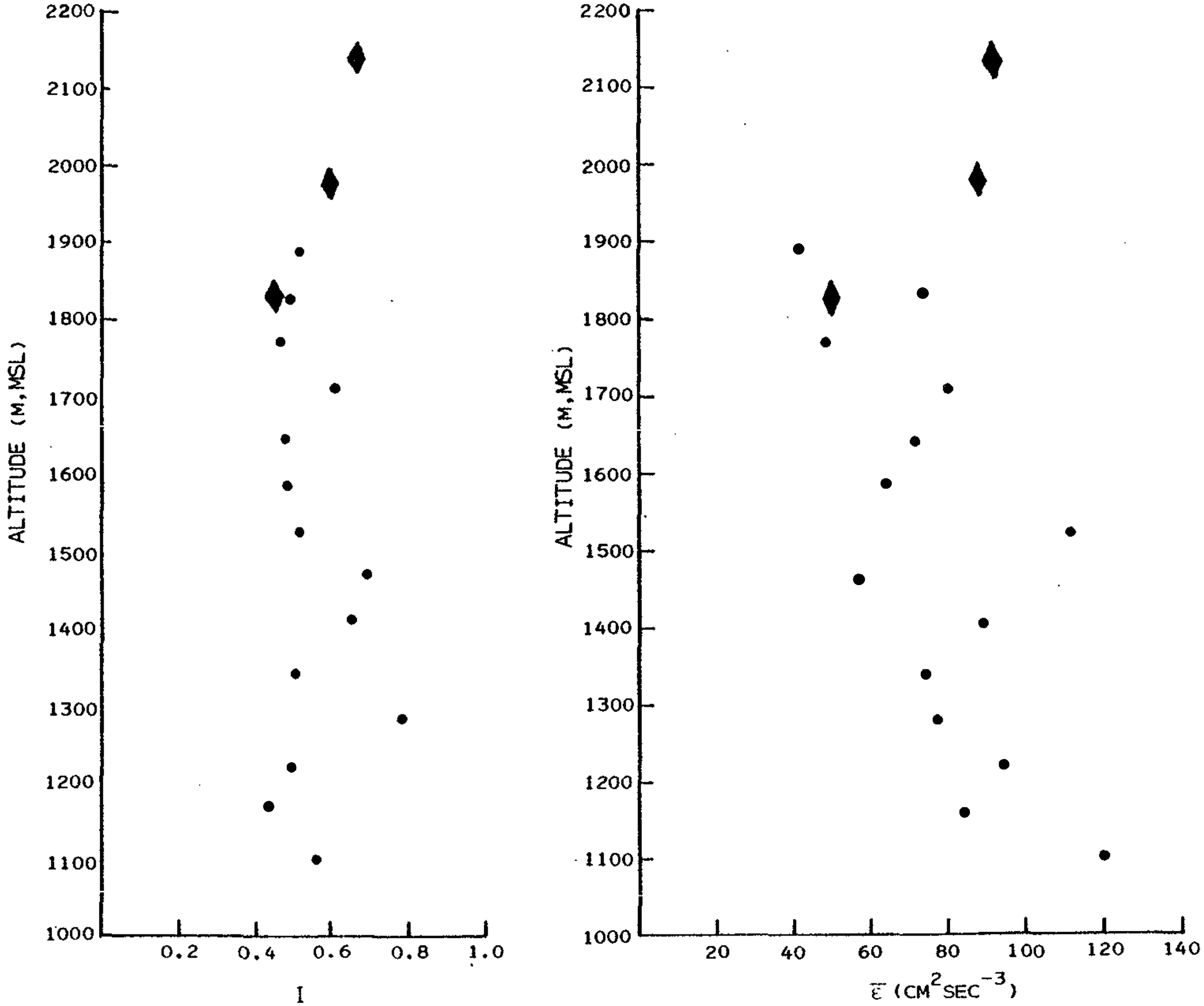


Figure 4.13-12 Turbulence measurements vs. altitude, Test 13. Diamonds indicate measurements from turbulence transects.

to the upper plant site as shown in Figure 4.13-7. The measurements indicate some increase in turbulence and intermittence above 1830 m MSL.

4.13.9 Summary of Test 13. Test 13 was conducted at the upper plant site assuming a stack height of 183 m. The tracer release was made at an altitude of 1920 m MSL. The meteorological conditions were characterized by light winds and neutral lapse rates. Under the influence of well-developed convective activity the plume was brought to the ground rapidly, impacting most heavily on the slopes west and northwest of the plant site. Concentrations there ranged to 1546 and 996 μgm^{-3} for half-hour and hour averages, respectively. Lower concentrations were found over a widespread area of the central Hat Creek Valley.

Oil-fog tracer data indicate that the plume had a strong tilt to the south with decreasing altitude indicating the lower level flow was up-valley. The normalized centerline concentration indicates rapid centerline dilution. Turbulence dissipation rates were within the values expected for C stability dispersion conditions.

In summary, this looping plume demonstrates that local convection may result in one-hour concentrations of at least 996 μgm^{-3} in the immediate vicinity of the plant site, and at the same time inject significant amounts of effluent into the up-valley circulation below.

4.14 Test Number Fourteen, August 11, 1976

Test 14 was conducted at the proposed upper plant site during the morning of August 11, 1976. A stack height of 366 m was assumed and plume rise of 366 m, giving an effective source altitude of 2105 m MSL. The meteorological conditions, characterized by rather low wind speeds, and a neutral though non-turbulent air-mass, were conducive to studying possible plume interaction with the valley circulation using a taller stack.

4.14.1 Synoptic Setting for Test 14. The high pressure system which had affected the project weather on August 9 and 10 was centered east of the project area on August 11. A weak cold front associated with a weakening closed low pressure system at 500 mb was located along the British Columbia coast. The low-level gradient flow over the project area was southerly. Cloudiness consisted of scattered altocumulus and cirrus.

Surface and 500-mb maps are shown in Figure 4.14-1.

4.14.2 Meteorological Parameters for Test 14. Meteorological parameters measured during this test include temperature lapse rates, surface winds and winds aloft. Temperature soundings were made by the NAWC tracer aircraft and double-tracked minisonde ascents. Surface winds were monitored by the B. C.Hydro meteorological station network. Double-tracked pilot balloon ascentions provided data on flow patterns aloft.

The temperature soundings from this test are presented in Figure 4-14-2. These show that stability conditions at plume height were slightly stable to near neutral throughout the test. The plant site soundings show a weak (1°C) surface-based inversion extending to 1600 m MSL (200 AGL) in the early morning which was weakened, lowered, and finally dissipated by 0900 PST. Other soundings show a somewhat stronger radiation inversion over the Upper Hat Creek Valley (Finney Lake) extending to 1600 m MSL or about 400 m AGL. A sounding over Upper Scottie Creek, 27 km northeast of the plant site, at 0730 PST, shows a dissipating radiation inversion which appears to have extended to about 350 m AGL. A final aircraft sounding, made 15 km east of Ashcroft, over

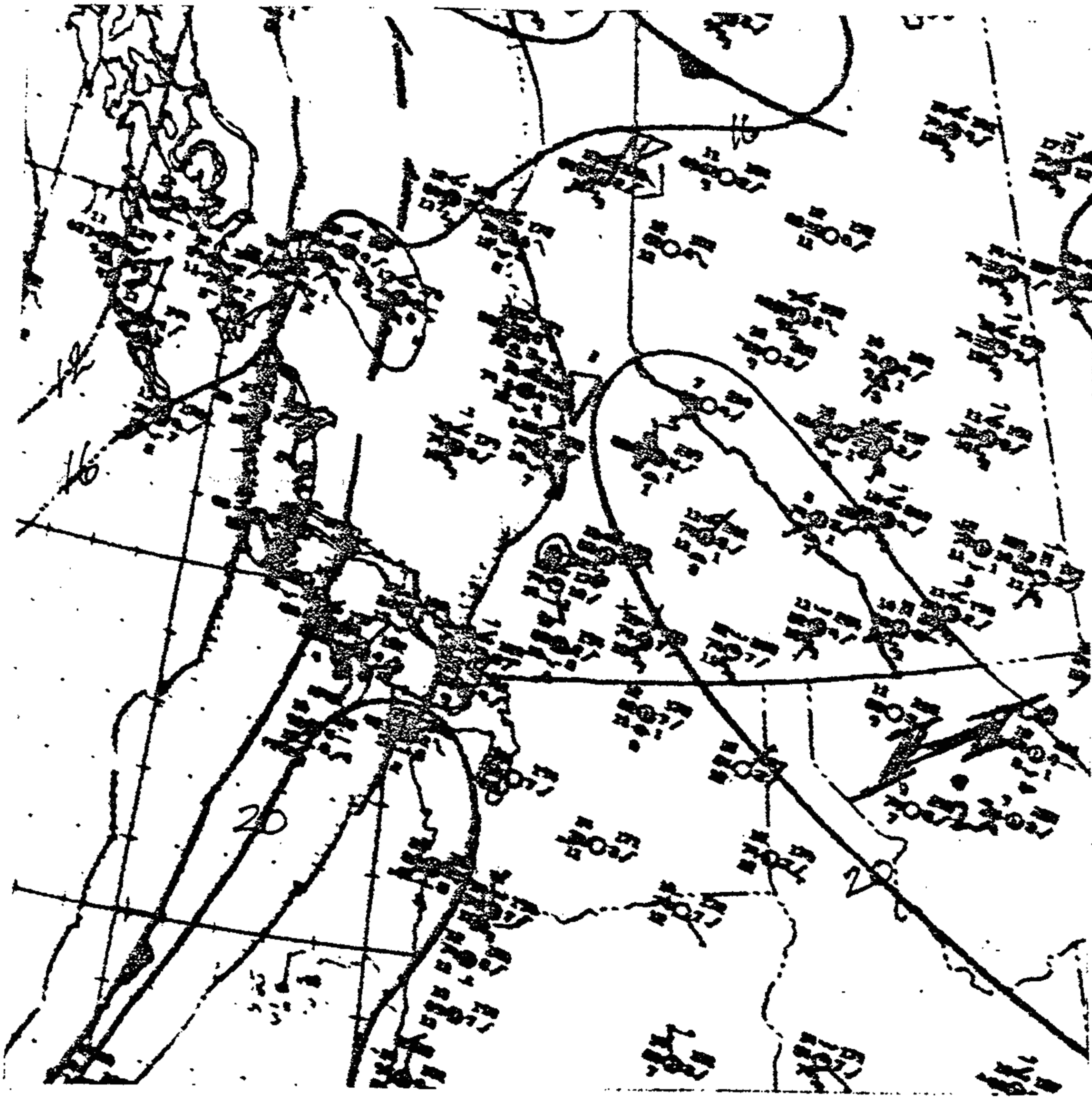


Figure 4.14-1   Surface and 500 mb maps, Test 14, August 11, 1976, 0400 PST.

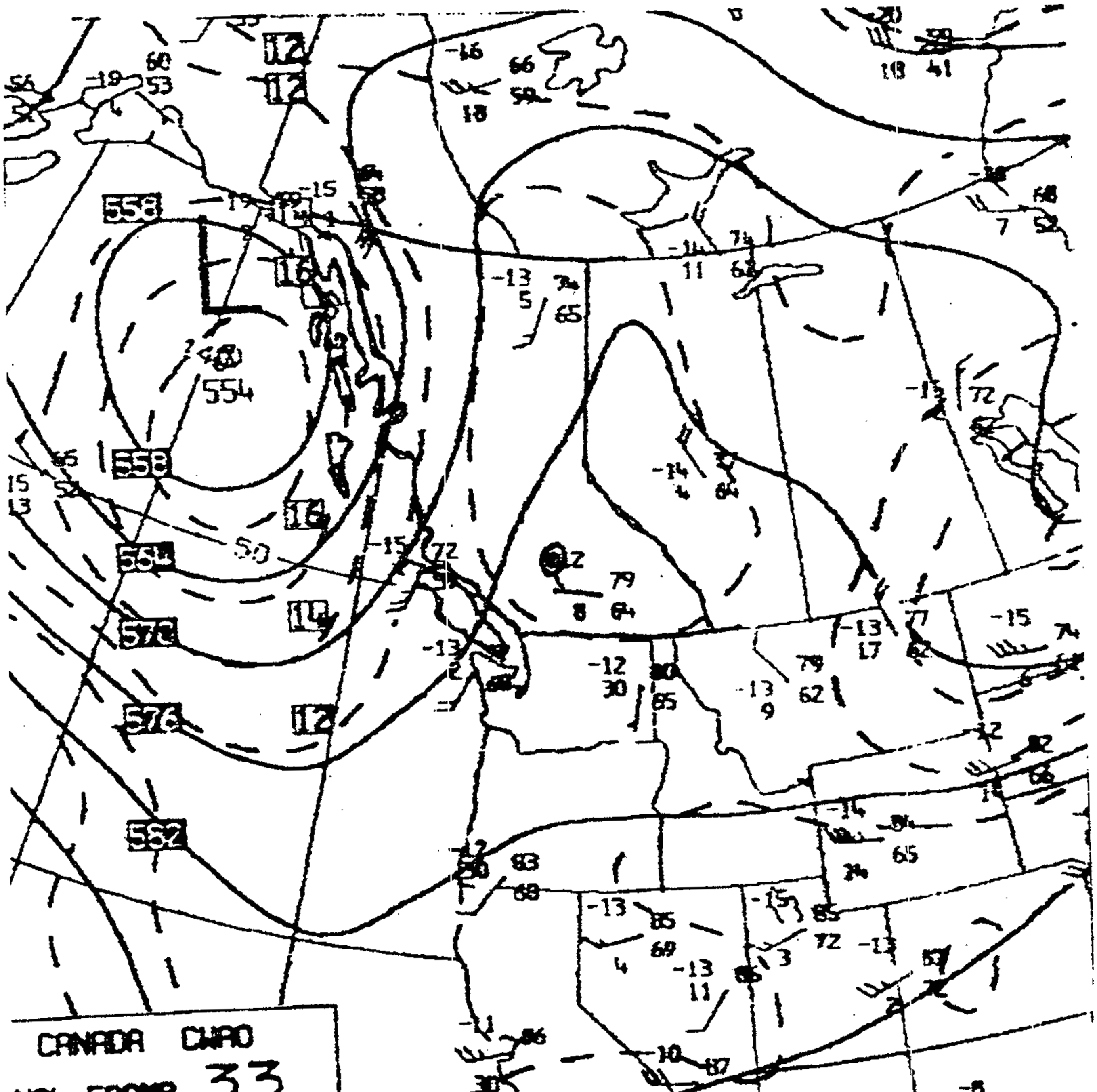


Figure 4.14-1 (Cont'd).

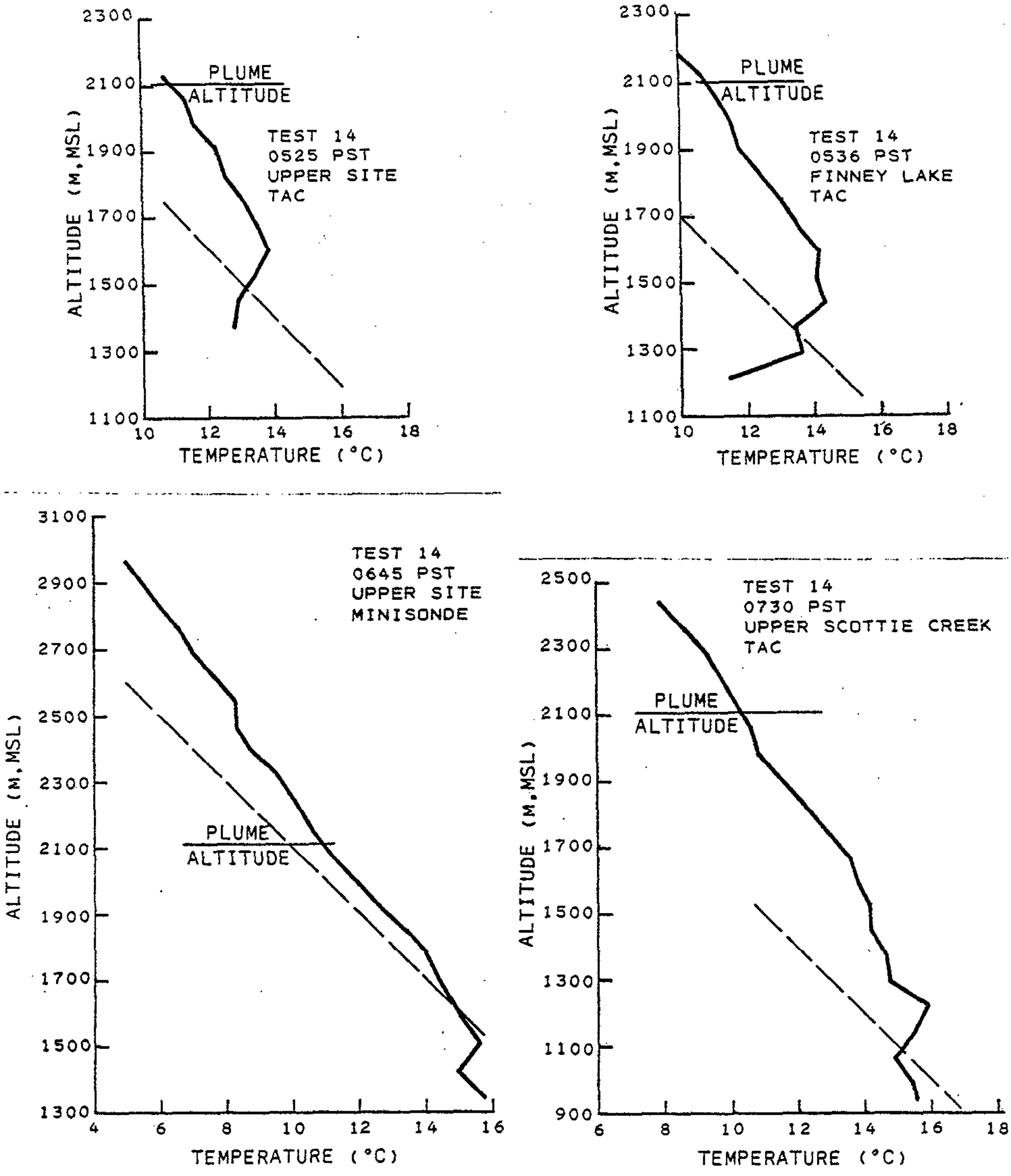


Figure 4.14-2 Vertical temperature profiles measured during Test 14.

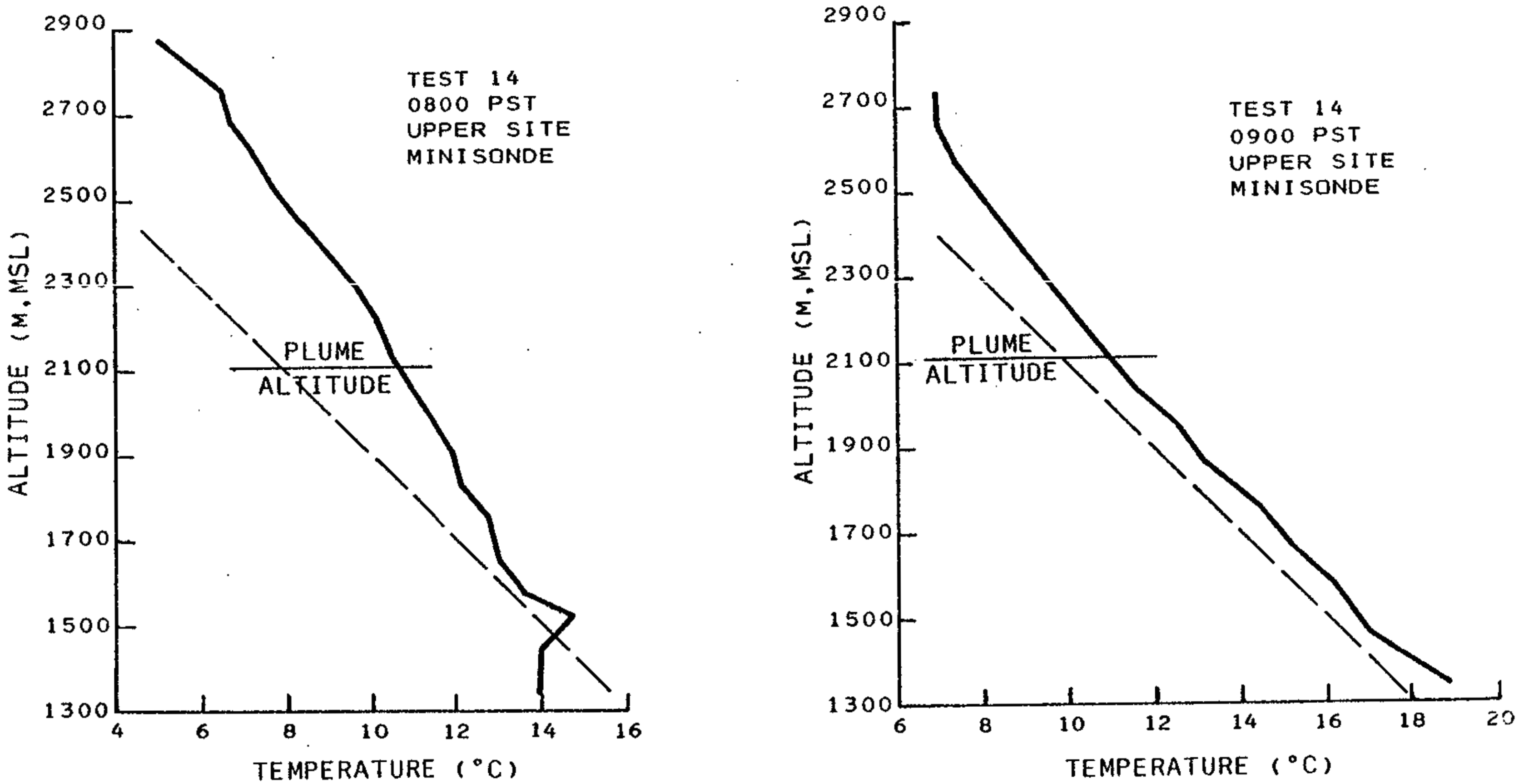


Figure 4.14-2 (Cont'd).

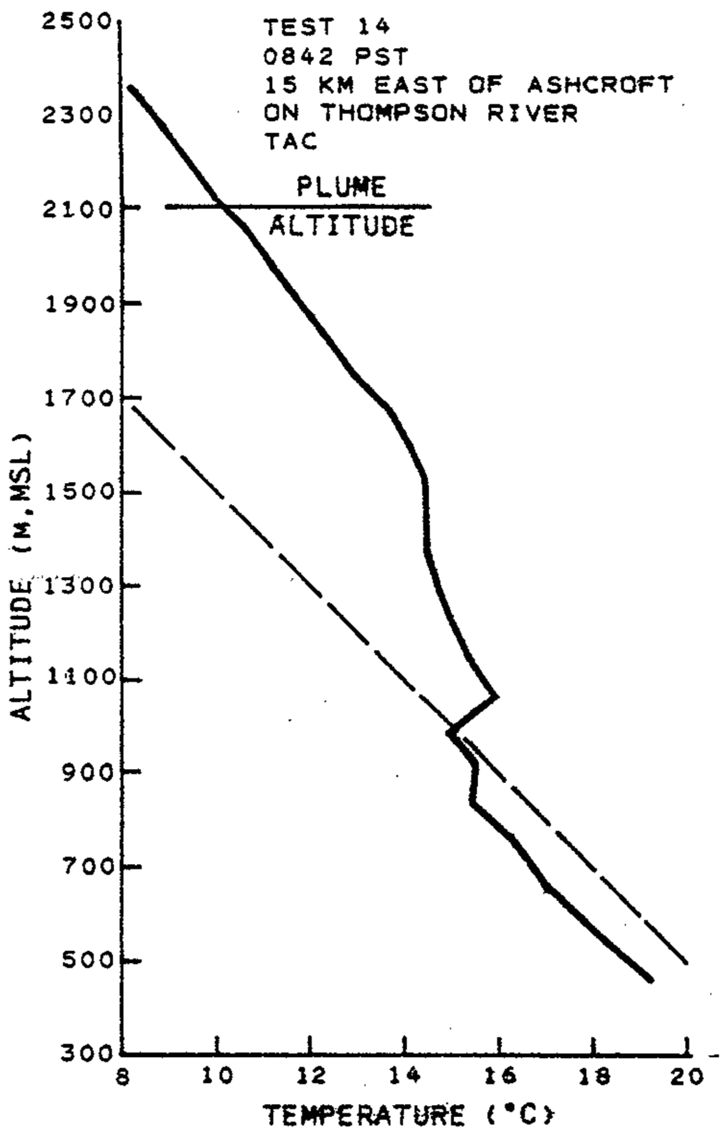


Figure 4.14-2 (Cont'd).

the Thompson River, shows near neutral conditions at plume altitude, a small inversion between 1000 and 1100 m MSL, and neutral conditions to the surface.

The surface wind data from this test may be found in Volume II, Field Data. These data show that surface winds were generally down-valley until 0800-0900 PST, when up-valley flow began. Average speeds ranged from calm to 2.5 m/s.

The winds aloft data are presented in the form of wind direction and wind speed time sections, Figures 4.14-3 and 4.14-4, respectively. These show that plume altitude winds were south to southwest at 3-4 m/s, during the release. Winds became slightly more westerly towards the end of the test and dropped to 2-3 m/s. These observations suggest that the plume was above the stronger influences of the valley circulation. At lower levels, wind speeds were higher (up to 5 m/s) in the early morning, but dropped off as the flow shifted from southwest (down-valley component) to northwest (up-valley component).

4.14.3 Tracer Dissemination, Test 14. The pertinent tracer dissemination parameters for Test 14 are given in Table 4.14-1, below.

Table 4.14-1 Duration and source strength of tracer release number 14.

Location: Upper Site
Altitude: 2105 m MSL
Simulated Stack Height: 366 m
Stability Classification: D

Tracer	Time On (PST)	Time Off (PST)	Total Released (g)	Source Strength (g/s)
SF_6	0537	0637	18,160	5.04
Oil Fog (1)	0537	0612	108,900	52.3
Oil Fog (2)	0629	0637	N/A	N/A

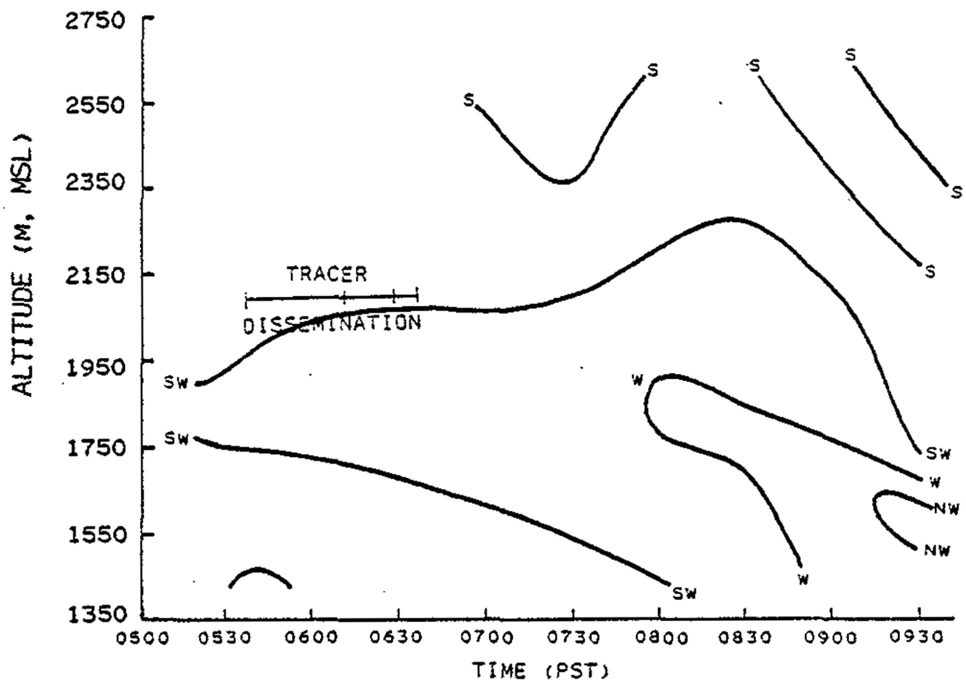


Figure 4.14-3 Time vs. altitude display of wind directions aloft measured during Test 14. Speeds are given in m/s.

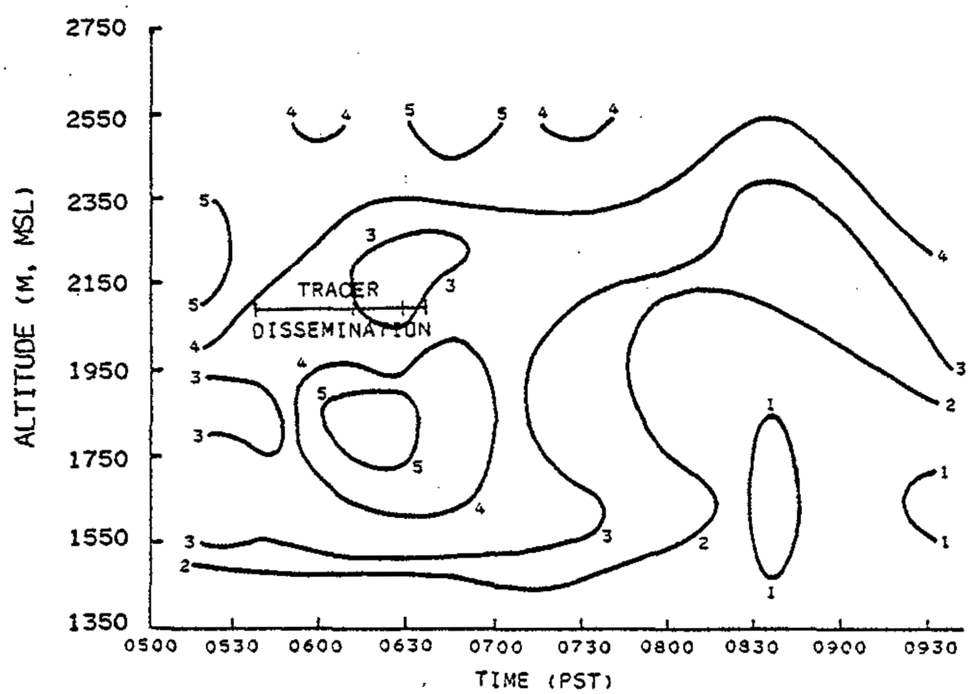


Figure 4.14-4 Time vs. altitude display of wind speeds aloft measured during Test 14. Speeds are given in m/s.

4.14.4 Visual and Photographic Observations. Plume transport was very similar to that of Test 6 (Section 4.6.4). The plume moved to the northeast at an average speed of 5.4 m/s during the first hour. Eighteen minutes after the release began, the neutral-appearing plume was almost over Gallagher Creek (Figure 4.14-5). Northeastward transport continued until the plume was over the Bonaparte River Valley near Carquile (Figure 4.14-6). After that, transport was more toward the north. Figure 4.14-7 shows the diffuse plume near Loon Lake at 0732 PST or one hour and 55 minutes after the release began. Observation continued for another 90 minutes as the diffuse plume continued moving toward the north and northeast. The leading edge was last visible near Green Lake, which is about 80 km north-northeast of the release site.

Plume outlines for the first 71 minutes of the test are shown in Figure 4.14-8.

4.14.5 Aerial Oil-Fog Measurements. Three sets of oil-fog crosswind patterns were flown during Test 14 at distances of 8.2, 18.0, and 32.0 km from the release. The locations are shown in Figure 4.14-9.

The passes for Set 1 were flown between 2225 and 2075 m MSL from 0609 to 0636 PST. The centerline altitude was found to be 2135 m MSL, 35 m above release altitude, where a maximum concentration of 8806 μgm^{-3} was measured. A plot of distance vs. concentration for that pass, together with a plot of altitude vs. maximum concentration for these passes appear in Figure 4.14-10. It can be seen that the bulk of the plume appears to be above release altitude. Also shown is the rather wide horizontal extent of the plume which was noticed in the visual and photographic observations. The values of σ_y and σ_z are plotted in Figure 4.14-11. Both indicate stable plume values. The normalized

Figure 4.14-5 Photo, Test 14. In this view towards the northeast, the tracer plume has reached Gallagher Creek, 0555 PST.

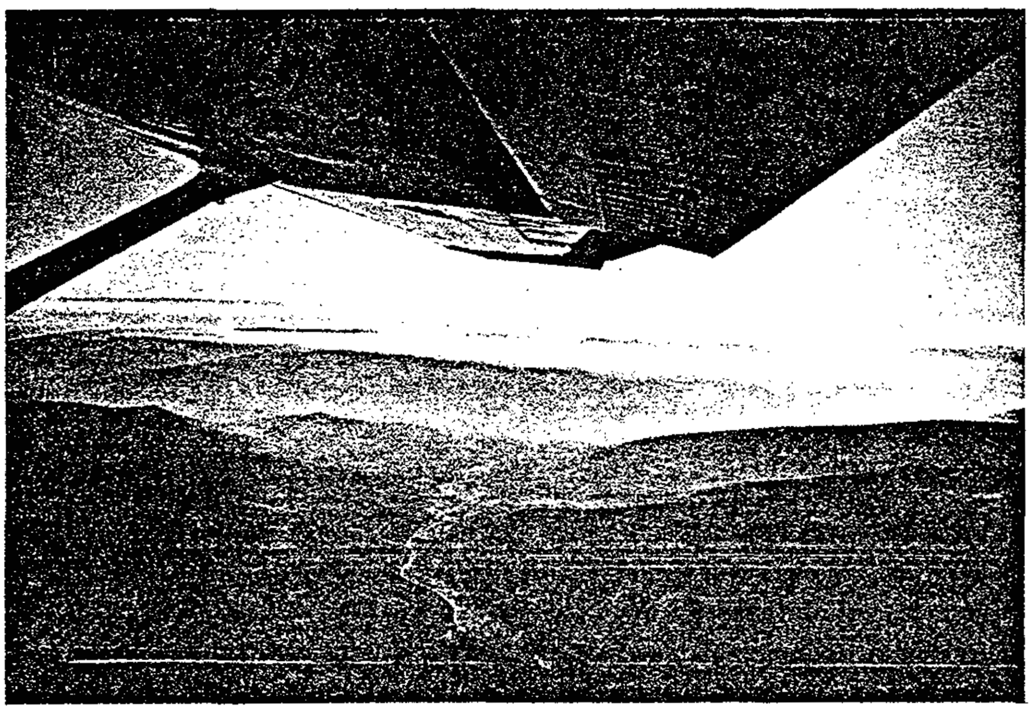


Figure 4.14-6 Photo, Test 14. At 0648 PST, the plume was over the Bonaparte River Valley. This photo was taken looking east down Hat Creek Valley.

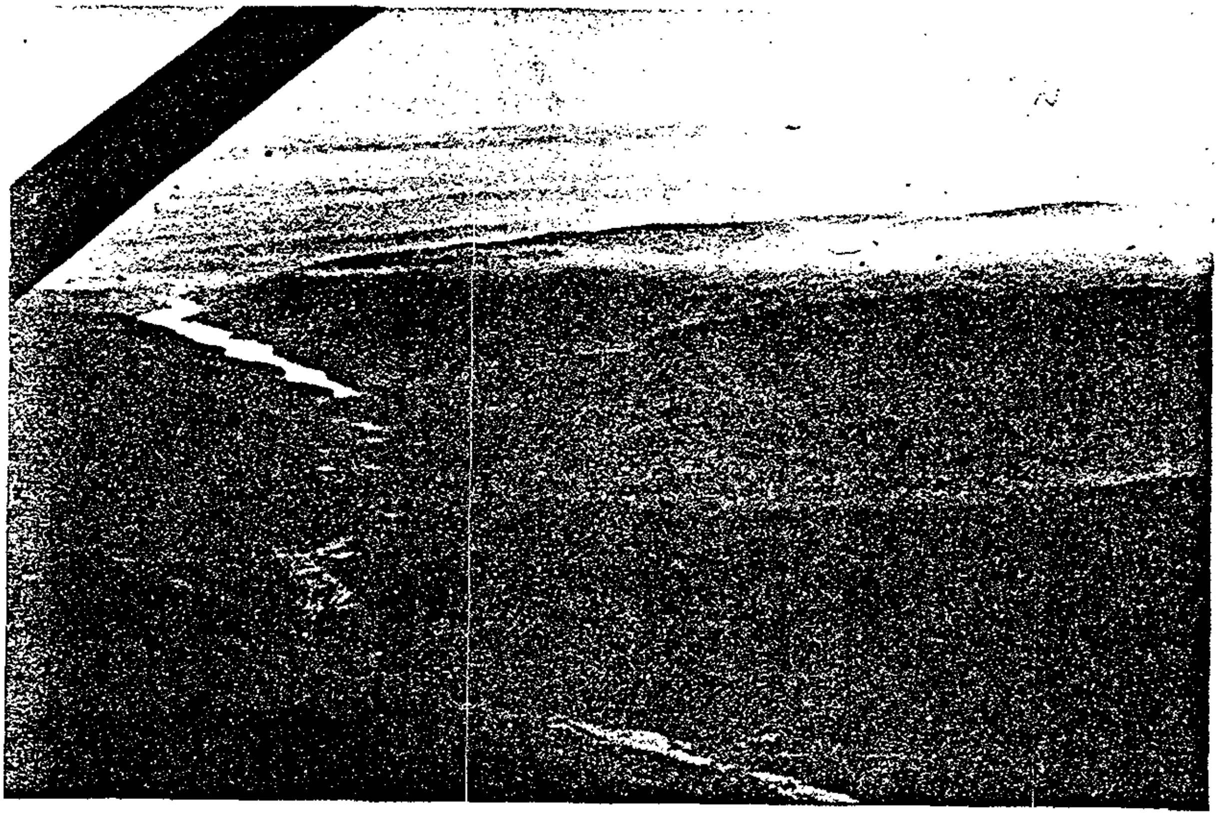


Figure 4-14-7 Photo, Test 14. Loon Lake (left center) and the Bonaparte River Valley can be seen in this 0732 PST photo. The diffuse plume, which was being transported to the north (right to left), shows little evidence of downward mixing.

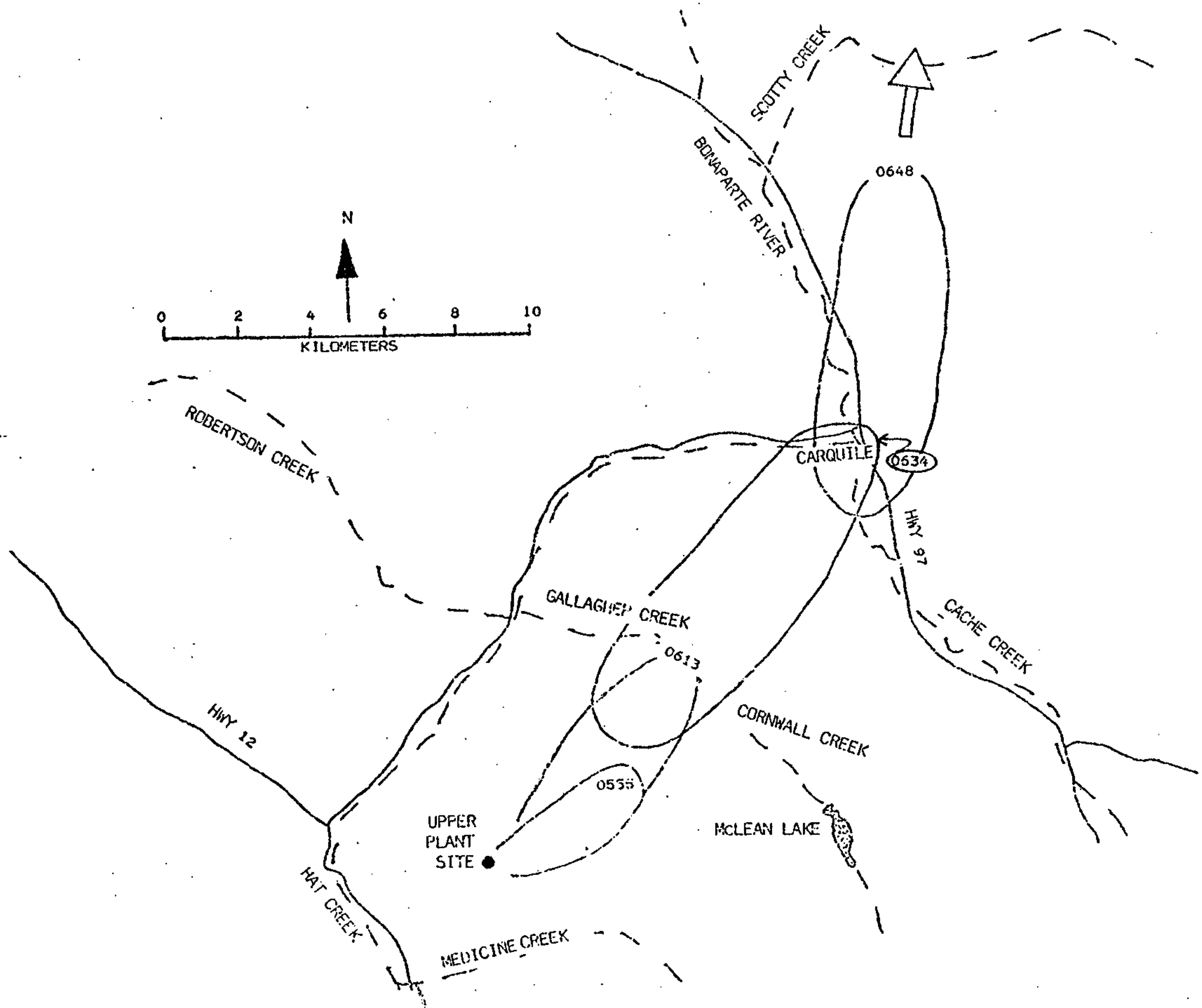


Figure 4.[illegible]8. Plume outlines for the first 71 minutes of Test 14.

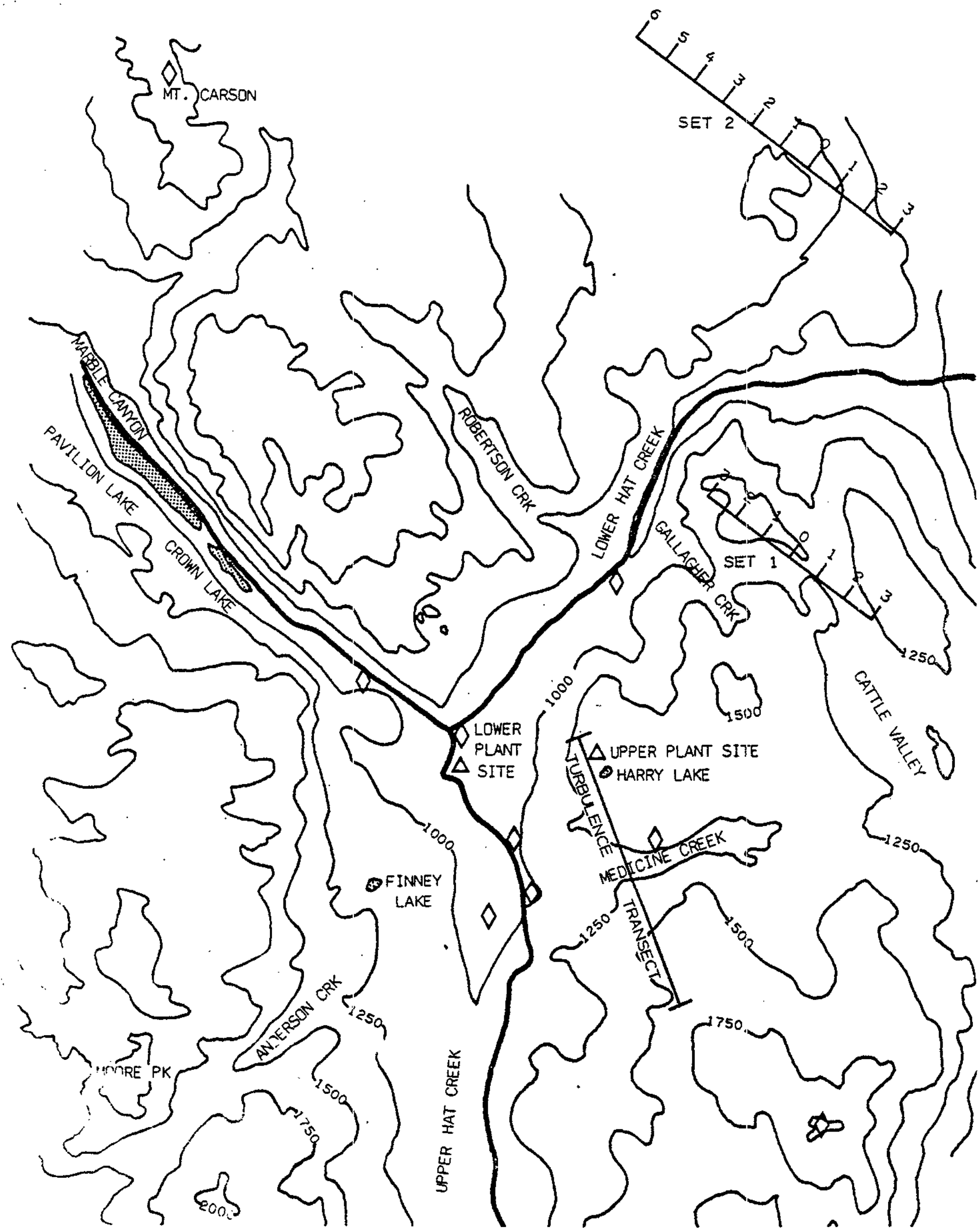


Figure 4.14-9 Locations of oil-fog crosswind patterns and turbulence transects, Test 14. Distances are in kilometers.

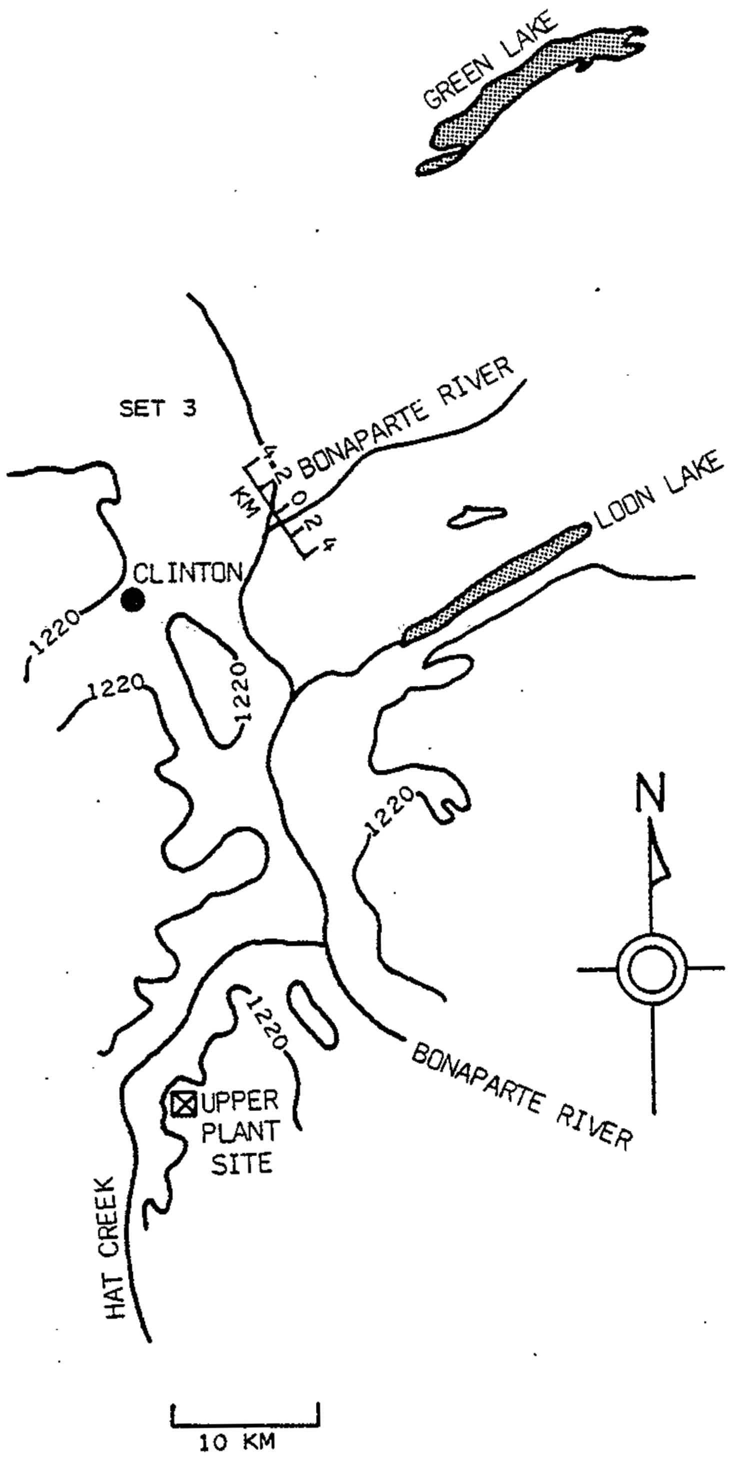


Figure 4.14-9 (Cont'd).

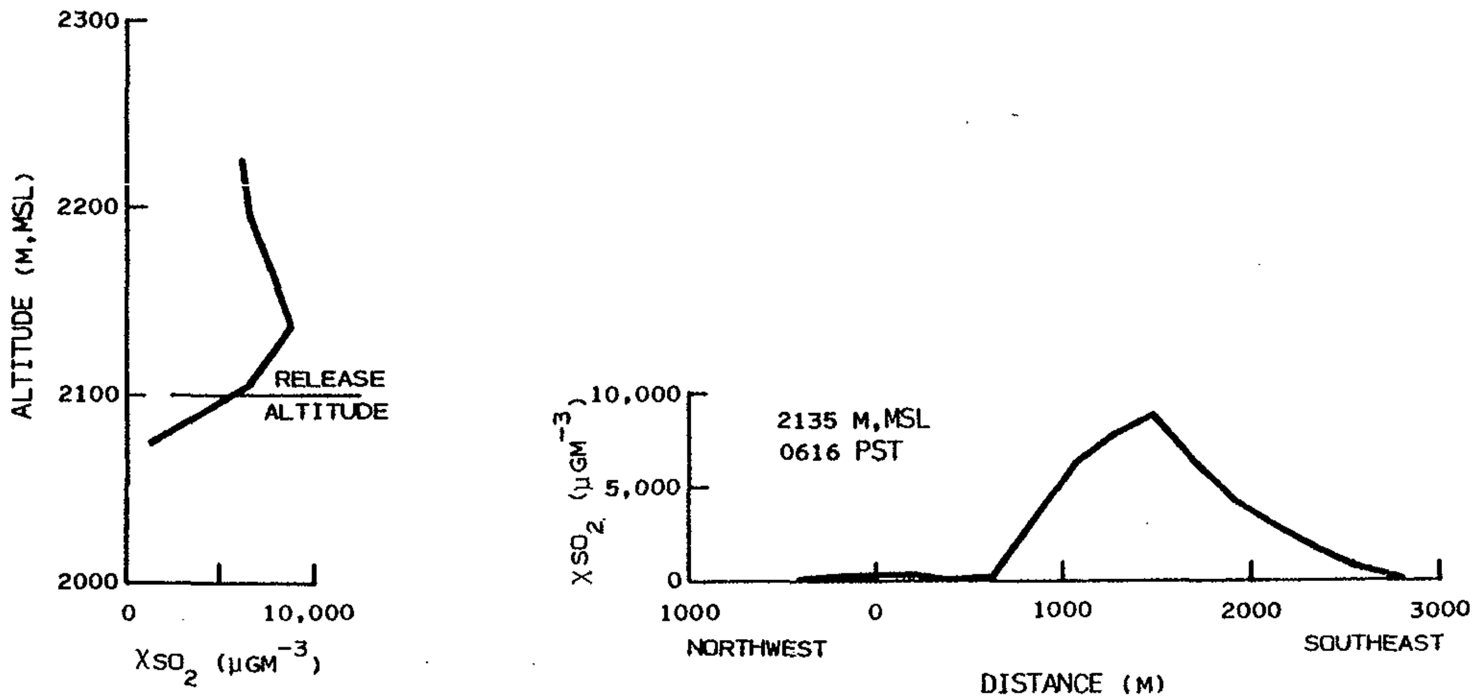


Figure 4.14-10 Horizontal and vertical plume centerline distributions, Test 14, Set 1.

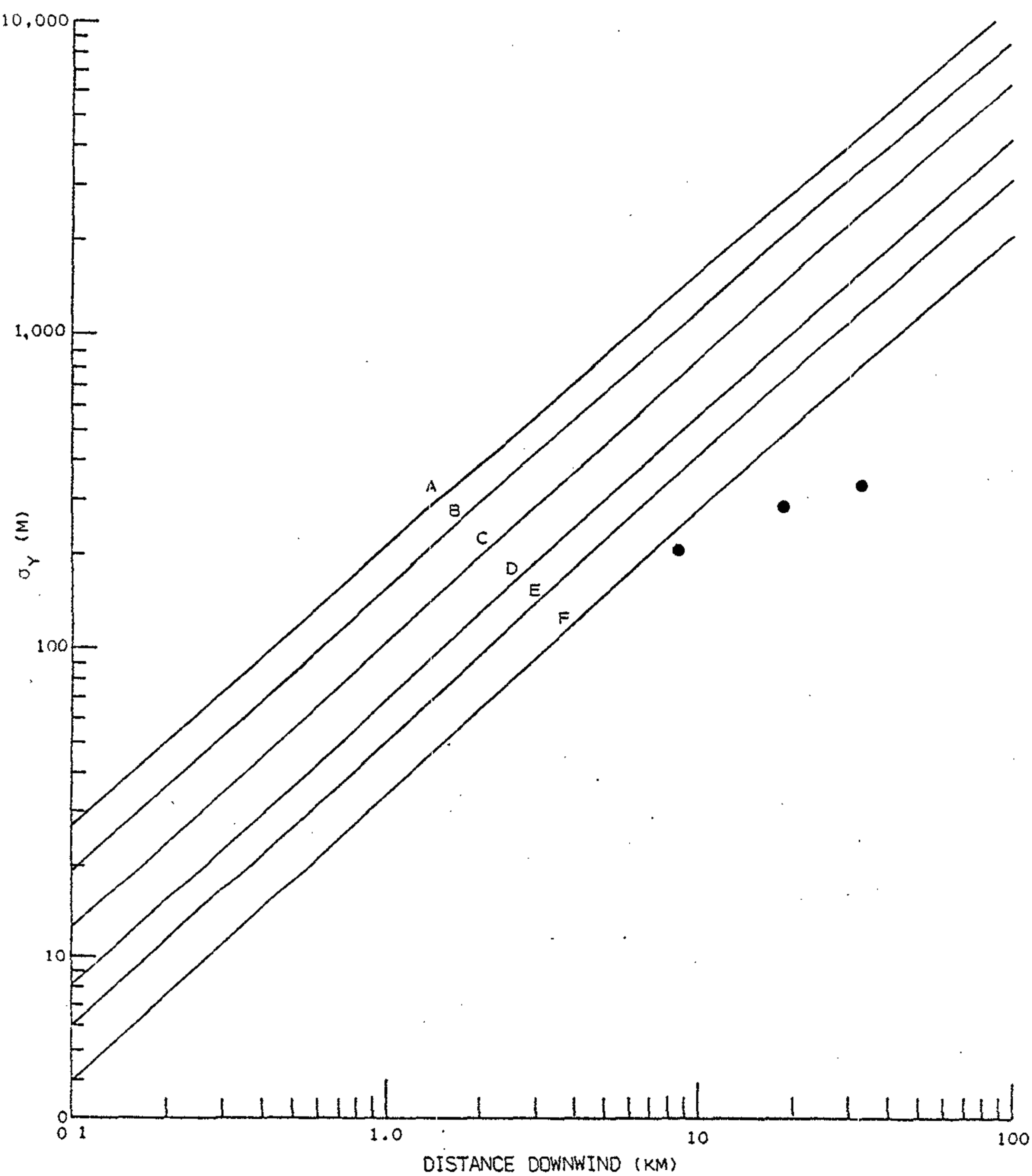


Figure 4.14-11 Measured values of σ_y and σ_z, Test 14.

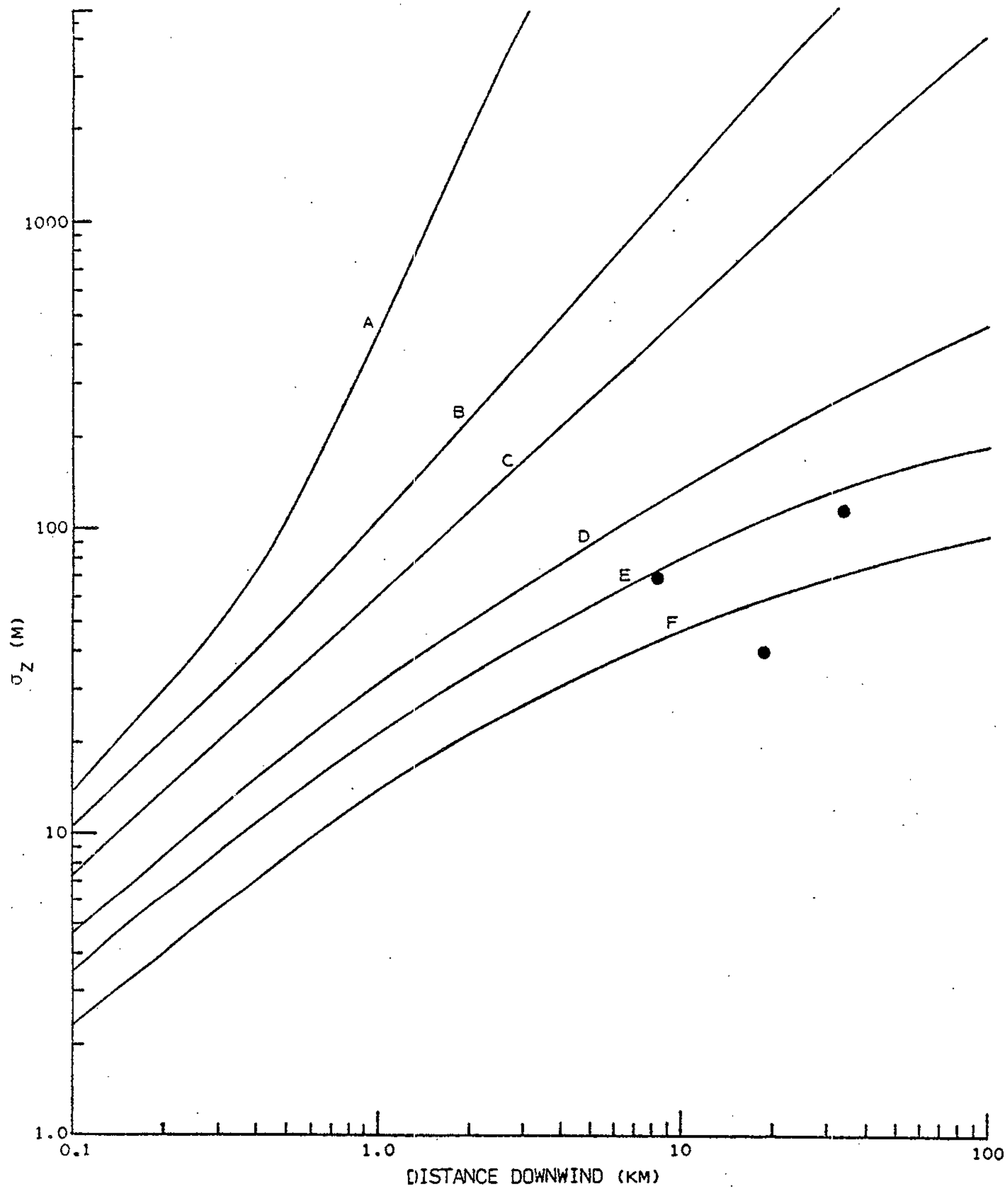


Figure 4.14-11 (Cont'd).

centerline concentration, $\frac{X\bar{u}}{Q}$, indicates a dilution rate nominal for E stability. The value is plotted in Figure 4.14-12.

The second set of oil-fog crosswinds were flown over the hills just north of the mouth of Lower Hat Creek Valley from 0652-0720 PST. Nine passes were made at altitudes between 2440 and 2165 m MSL. The maximum concentration, equivalent to 7863 μgm^{-3}, was found at 2350 m MSL. The vertical and horizontal plume centerline distributions, Figure 4.14-13, show the plume layer to be about 200 m above where it was found during Set 1. The centerline location indicates the plume trajectory turned sharply to the north near the location of Set 1. This observation probably reflects a degree of channeling of flow up the Bonaparte River Valley.

The values of σ_y and σ_z, plotted in Figure 4.14-11, indicate continued very stable plume behavior. The value of σ_z appears lower than expected. The normalized maximum concentration, $\frac{X\bar{u}}{Q}$, is plotted in Figure 4.14-12 and indicates some slowing in the rate of dilution.

The third set of passes was flown about 10 km northwest of the town of Clinton, from 0801 and 0821 PST. Eight passes were made at altitudes between 2105 and 2470 m MSL. The maximum measured concentration of 3774 μgm^{-3} was found at 2350 m MSL. The horizontal and vertical centerline distributions are presented in Figure 4.14-14. It can be seen that the measurable portion of the plume was about 1.5 km wide and at least 375 m thick. The location of the plume suggests that the trajectory followed the Bonaparte River Valley.

The values of σ_y and σ_z are plotted in Figure 4.14-11. Stable to very stable conditions are indicated. The normalized centerline concentration, $\frac{X\bar{u}}{Q}$, indicates a continued dilution rate nominal for F stability conditions (Figure 4.14-12).

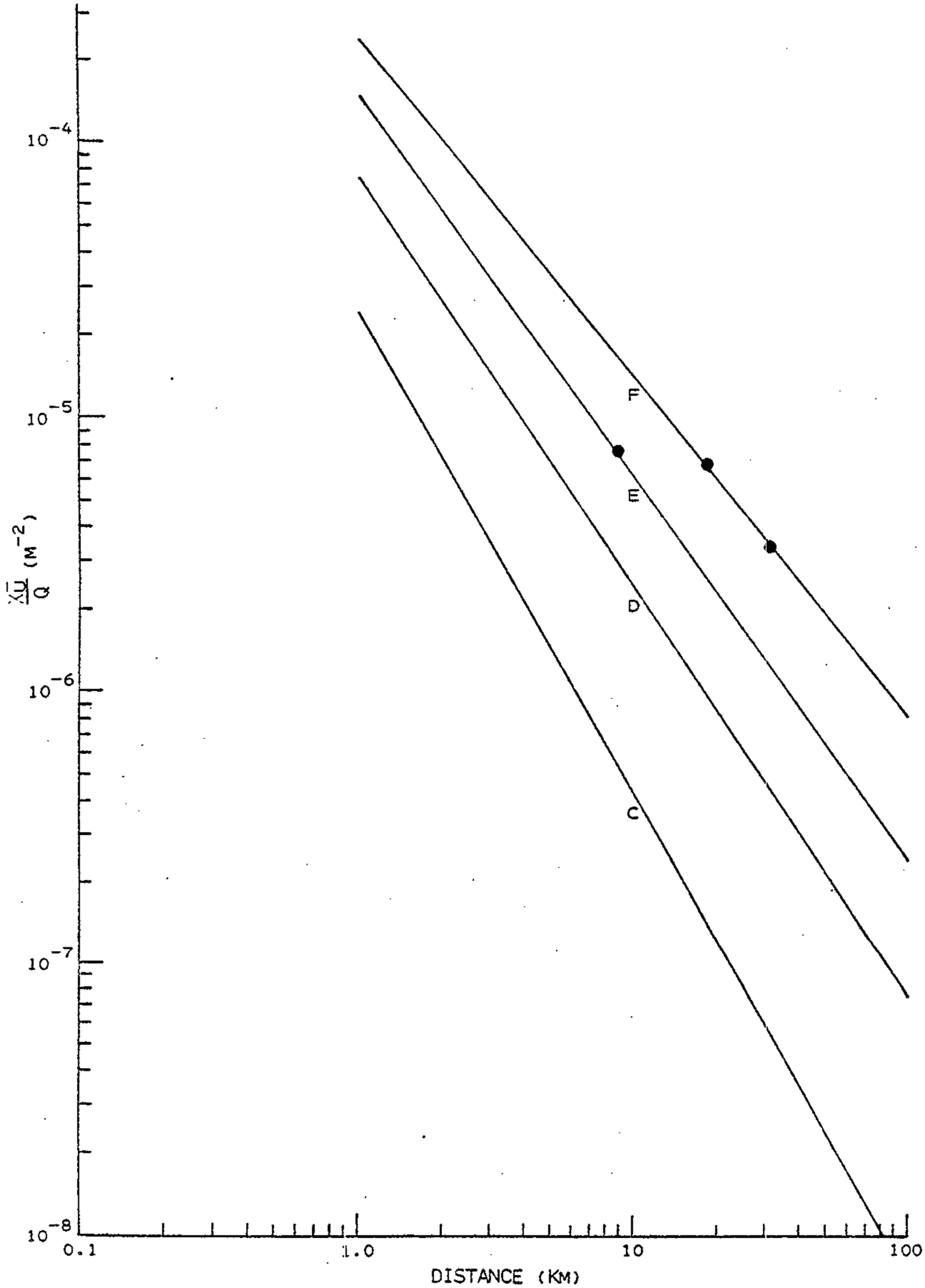


Figure 4.14-12 Measured values of $\frac{\chi \bar{u}}{Q}$, Test 14.

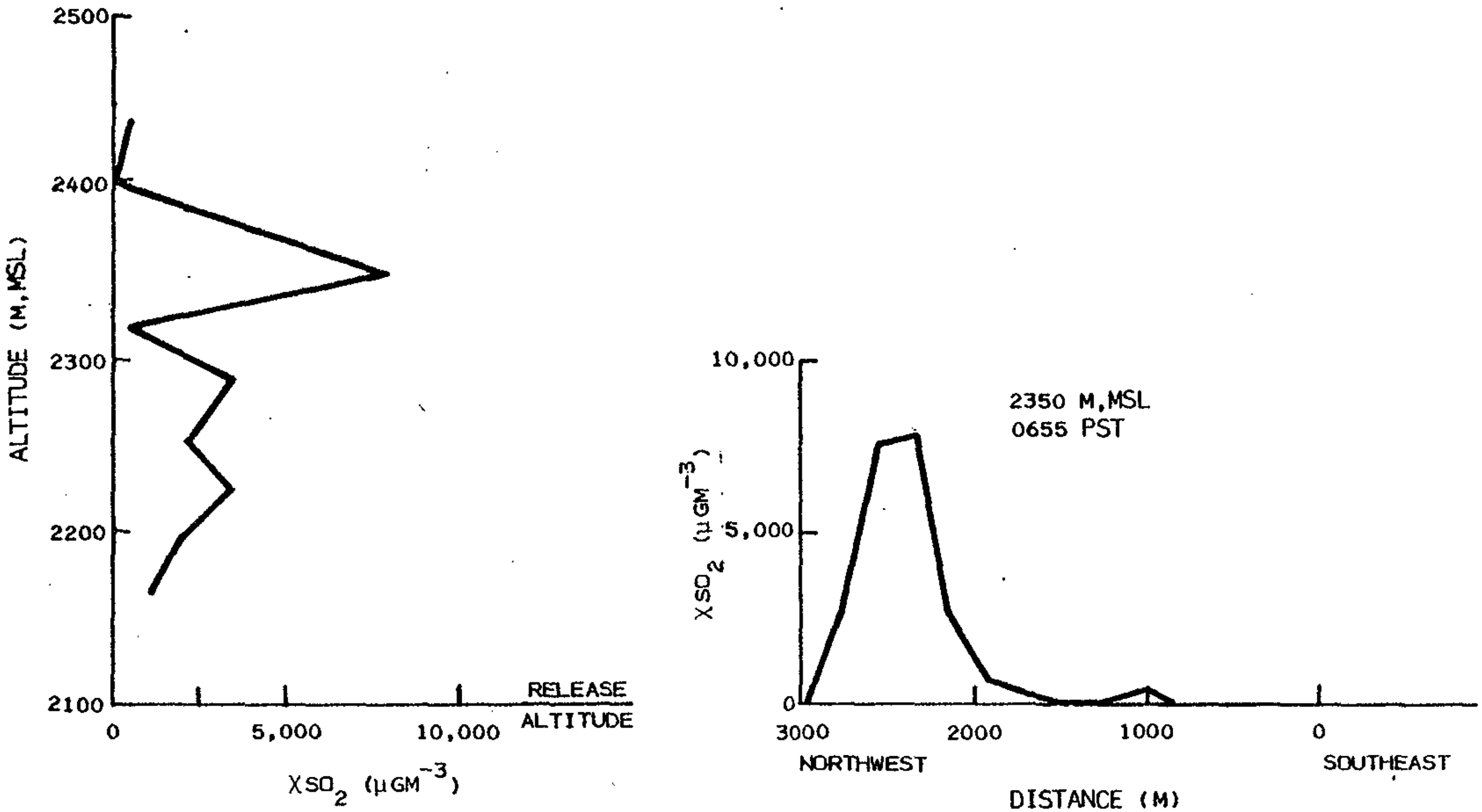


Figure 4.14-13 Horizontal and vertical plume centerline distributions, Test 14, Set 2.

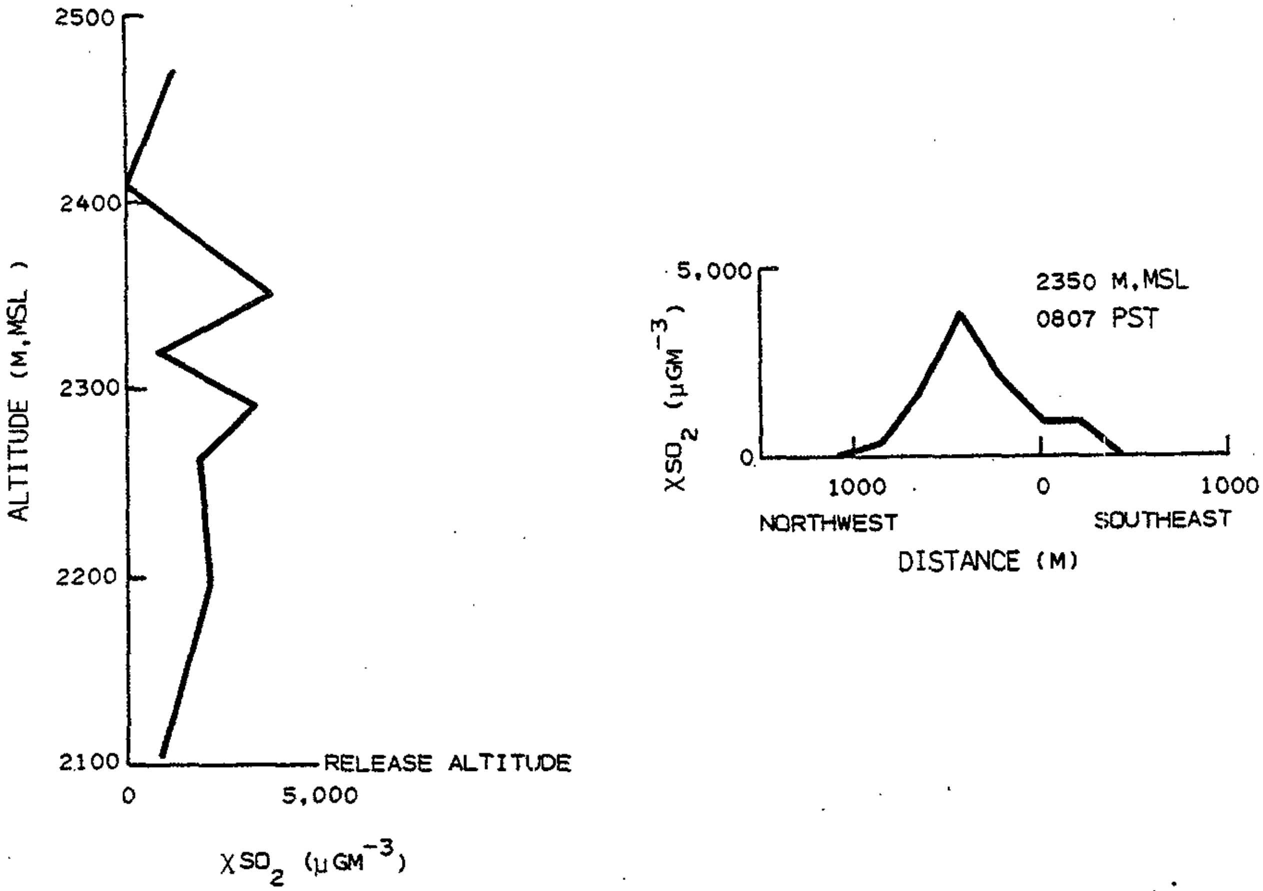


Figure 4.14-14 Horizontal and vertical plume centerline distributions, Test 14, Set 3.

4.14.6 Aerial SF_6 Measurements. Due to the necessity of transporting ground samplers long distances, no aerial SF_6 samples were taken during this test.

4.14.7 Surface SF_6 Measurements. A total of 17 samplers were deployed for this test at distances up to 43 km from the release point. Their locations are shown in Figure 4.14-15 with supplementary information given in Table 4.14-2. Four of the samplers (14S2, 14S3, 14S5, and 14S9) showed measurable SF_6, though the concentration were just above threshold limits and

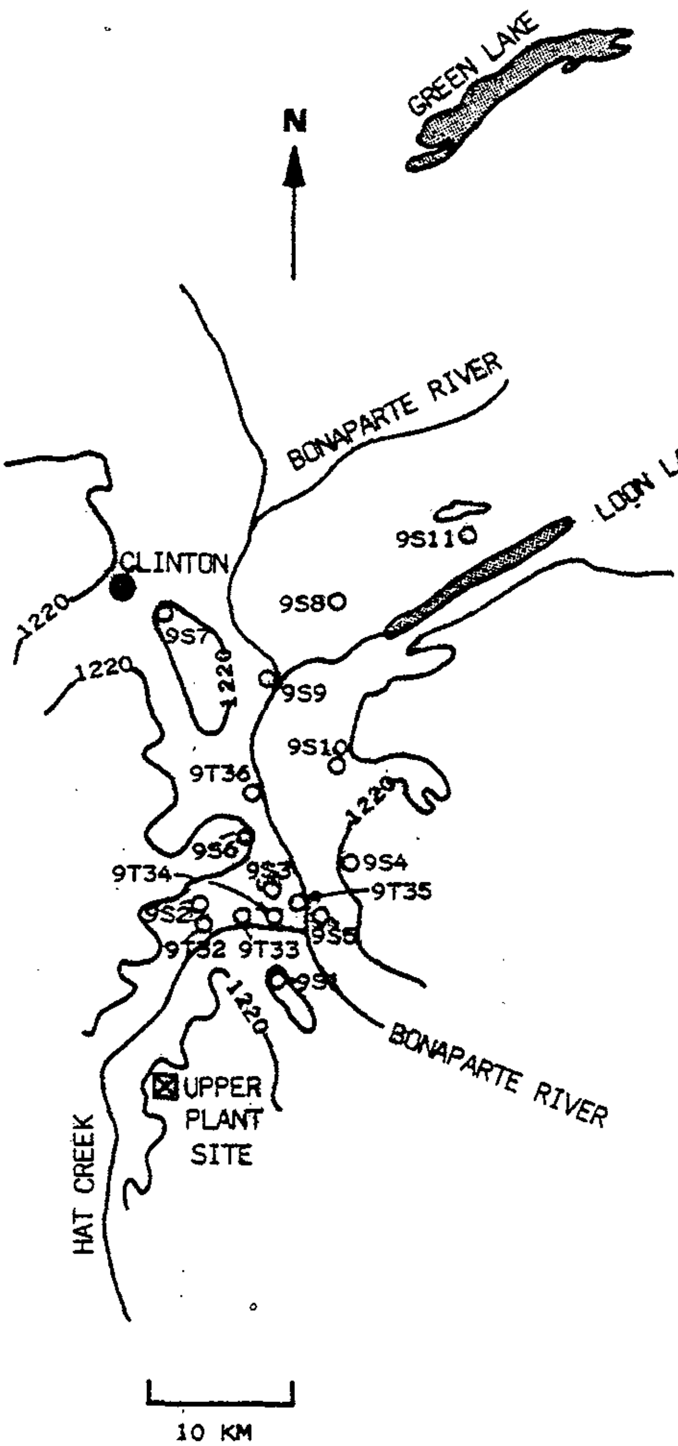


Figure 4.14-15 Location of surface SF_6 samplers, Test 14.

Table 4.14-2 Surface SF_6 sampler information.

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
14S1	10.0	1325	0646	0717	30	0	0
			0716	0746	30	0	0
			0746	0816	30	0	0
			0816	0836	30	0	0
			0846	0916	30	0	0
			0916	0946	30	0	0
14S2	12.2	1035	0649	0729	30	0	0
			0729	0759	30	0	0
			0759	0829	30	<21	<28
			0829	0859	30	0	0
			0859	0929	30	Malf.	-
14S3	15.6	990	0705	0735	30	0	0
			0735	0805	30	0	0
			0805	0835	30	0	0
			0835	0905	30	<21	<28
			0905	0935	30	0	0
14S4	19.1	1220	0715	0745	30	Malf.	-
			0745	0815	30	0	0
			0815	0845	30	0	0
			0845	0915	30	0	0
			0915	0934	19	0	0
14S5	16.3	670	0720	0750	30	0	0
			0750	0820	30	<21	<28
			0820	0850	30	0	0
			0850	0920	30	<21	<28
			0920	0938	18	0	0
14S6	17.7	1220	0737	0830	53	0	0
			0830	0927	57	0	0
14S7	33.6	975	0744	0826	42	0	0
			0826	0923	57	0	0
14S8	36.8	1145	0753	0815	23	0	0
			0815	0915	60	0	0

Table 4.14-2 (Cont'd)

Sample Number	Distance From Release (km)	Altitude (m, MSL)	Time On - Time Off (PST)		Sampling Time (min)	XSO_2 (μgm^{-3})	
						Ambient	NTP
14S9	22.4	550	0730	0800	30	0	0
			0800	0830	30	0	0
			0830	0900	30	0	0
			0900	0930	30	<21	<28
			0930	1000	30	0	0
			1000	1030	30	<21	<28
14S10	21.3	1005	0735	0835	60	0	0
14S11	43.2	1130	0845	0945	60	0	0
14S12	35.2	1375	0850	0950	60	Malf.	-
14T32	10.2	732	0655	0753	58	0	0
			0753	0839	46	0	0
			0839	0914	35	Malf.	-
14T33	12.3	610	0707	0800	53	0	0
			0800	0846	46	0	0
			0846	0916	30	0	0
14T34	13.9	520	0715	0804	49	0	0
			0804	0851	47	0	0
			0851	0920	29	0	0
14T35	10.6	550	0723	0808	45	0	0
			0808	0857	39	0	0
			0857	0924	27	0	0
14T36	17.7	550	0728	0811	43	0	0
			0811	0900	49	0	0
			0900	0927	27	0	0

represented SO_2 concentrations of less than 21 μgm^{-3} for half-hour samples, and less than 11 μgm^{-3} for hour samples.

4.14.8 Turbulence Measurements. Turbulence measurements from this test come from the three sets of oil-fog crosswinds and from turbulence transects (see map, Figure 4.14-9). The data, plotted in Figure 4.14-16, indicate turbulence was fairly light during the oil-fog patterns. Intermittence values were moderate. The values from the turbulence transects, which were made south from the release point, may indicate increasing turbulence below 2000 m MSL.

4.14.9 Summary of Test 14. The Test 14 tracer plume was released from the upper plant site assuming a stack height of 366 m. Release altitude was 3105 m MSL. Meteorological conditions at plume level were characterized by southwesterly winds of 3-4 m/s and slightly stable lapse rates. Upon release, the plume moved to the northeast following the general line of Lower Hat Creek, then turning north, up the Bonaparte Valley. The plume continued north past Clinton and was last visible over Green Lake 80 km from the release site. During transport the plume showed little evidence of downward mixing and surface samplers detected only threshold concentrations of SF_6. Aerial oil-fog data indicate that the plume rose somewhat as it moved down Hat Creek, with no evidence of vertical mixing. Normalized centerline concentrations from 8, 18, and 32 km downwind show rates of dispersion nominal for E-F stability. Turbulence dissipation rates were also typical of stable conditions.

In summary, it is concluded that under the meteorological conditions experienced, the release altitude of 2105 m MSL was sufficient to prevent plume entrainment in local circulations as it was transported more than 80 km across moderately rugged terrain. The basically stable-appearing plume experienced a good

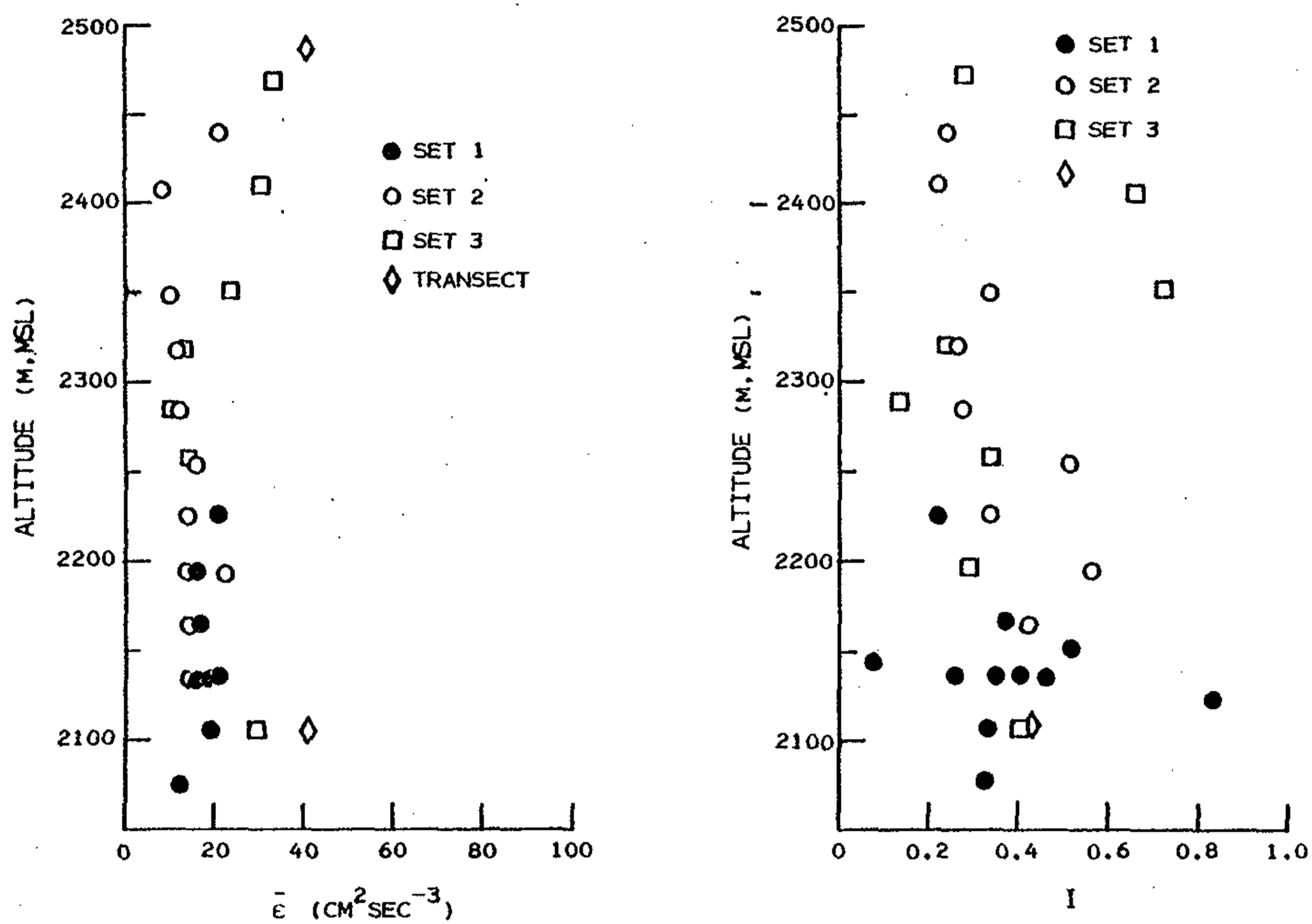


Figure 4.14-16 Turbulence measurements vs. altitude, Test 14.

deal of horizontal spreading, but little vertical mixing and appeared to ascend during the initial transport. As a result of these factors, surface impact was negligible.

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NAWC personnel participating in this study included Mr. Cliff R. Scholle, chemical engineer, who designed and fabricated the bag samplers and performed gas chromatograph analysis; Messrs. Alan J. Anderson and Joe L. Sutherland, air quality meteorologists, who participated as project photographers, and Ms. Heather Schick, who supervised the data processing. Typing and assembly were accomplished by Mrs. Gloria Evans, Ms. Diane Zarnick, and Ms. Deborah Dal Zuffo.

About the Authors: Mr. Einar L. Hovind, Vice President, NAWC Air Quality Division, had overall supervision of the project. Mr. Timothy C. Spangler, Vice President, NAWC Intermountain Regional Office, was project director. Mr. Nicholas E. Graham, NAWC Climatologist, was assistant director and performed much of the detailed field data analysis.

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