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AIR FLOW LAND–SEA–AIR INTERFACE MONTEREY BAY, CALIFORNIA - 1971

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by
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AIR FLOW LAND-SEA-AIR INTERFACE
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Abstract

Air flow at the land-sea-air interface influences to a large extent the atmospheric conditions that determine the transport, dilution, and trapping of natural and man-made air pollutants in the coastal areas of Monterey Bay and the Salinas Valley. Analysis of the hourly air flow on a daily and and monthly basis indicates patterns of stagnation from midnight to noon of the following day with moderate to strong air flow during period 1300 to 2200. Throughout the year 1971 whenever flow is greater than 5 mph, the prevailing wind direction is onshore and from a westerly direction. Suggestions for urbanization and industrialization are made on the basis of an understanding of the atmospheric conditions which lead to trapping and dispersal of atmospheric waste.

Introduction

Air flow at the land-sea-air interface of Monterey Bay displays certain characteristics which have been described by Read (1971), Schroeder et al (1967), Bell (1968), and others. Essentially there is a differential heating across a coast line which often leads to a disturbance there that spreads laterally both inland and out to sea. There appears to be maximum acceleration of the low level flow at the land-sea-air interface and a low level jet maximum forms some 300 to 600 feet above sea level. Some distance shoreward there is a convergence zone in the horizontal wind field while at some distance seaward there is a divergence in the horizontal wind field. The low level wind maximum appears to be a feature of the morning and late afternoon winds for at least 40 miles inland into the Salinas Valley.

On the north and south sides of Monterey Bay, the topography may produce a large eddy in the flow, and wind speeds and directions measured there may be quite different than those measured at Moss Landing in the center of the bay near the historical mouth of the Salinas River. The wind field at Moss Landing is perhaps more representative of the undisturbed offshore flow.

Marine air flooding across the beach interface and into the valley becomes channeled by the topography. Edinger (1971) describes quite well what may happen to the marine air intrusion of a coastal air shed. The low level flow may be dammed by the steep slopes of the valley and especially at night when downslope (cold air drainage) prevails. In the day time the steep slopes may act as vents to permit the marine air to exit from the air shed. The day time heating causes the slopes to heat up and the air flow may be up the slopes and out of the air shed at the ridges.

The upper air flow over the ridges may be channeled and constrained into the valley as shown schematically in Figure 1. The channeled flow then may be either up or down the valley.

The low level marine air flow into the valley is quite turbulent and almost complete mixing takes place in this layer of air. The mixing and the height to which the mixing may occur depends upon the speed of the flow across the interface and into the valley. With high wind speeds the air mixes to greater heights than with low speed winds where the depth of the mixing level may be closer to the floor of the valley.

Figure 2 is a schematic of a vertical cross section through the valley and a temperature and dew point temperature sounding some 10 miles inland at Salinas, California. At the top of the mixed layer a temperature inversion forms. There is turbulent mixing in the marine layer and the air cools off rapidly with height up to the depth of the mixed layer. Above the mixed layer the air cools much more slowly. In a shallow layer, whose bottom edge is at the top of the mixed marine air, the temperature actually increases with height and this is called the inversion layer. With the presence of a temperature inversion the buoyancy force of uprising air is suppressed and the vertical dispersion of any pollutant is low. The dew point temperature, which is a measure of the amount of moisture in the air, also decreases with height in the marine mixed layer and then decreases very markedly at the base of the inversion layer indicating how dry that layer is and the pronounced separation between the lower moist air and the dry air above within the inversion layer. While we cannot measure the turbulent mixing shown in these diagrams, we can measure the vertical temperature profile and from well known

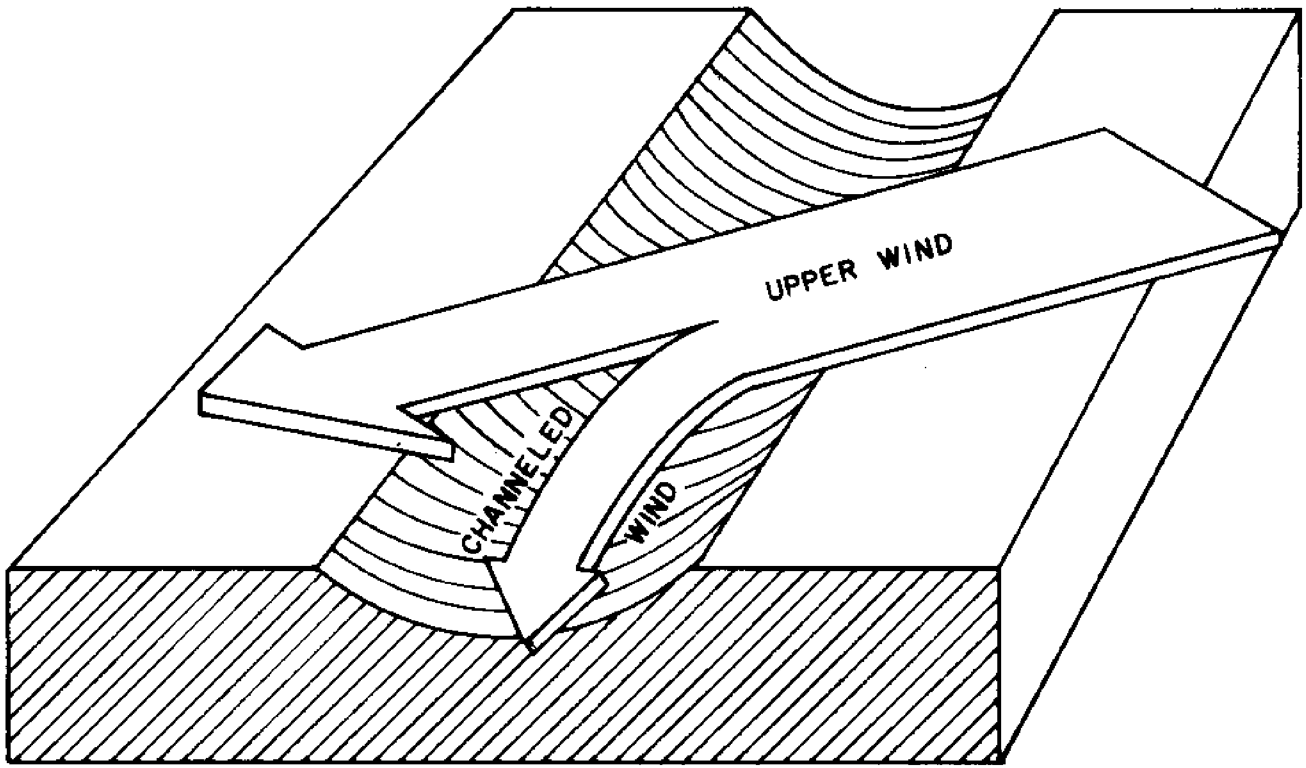


Figure 1. Channeled wind flow in the valley.

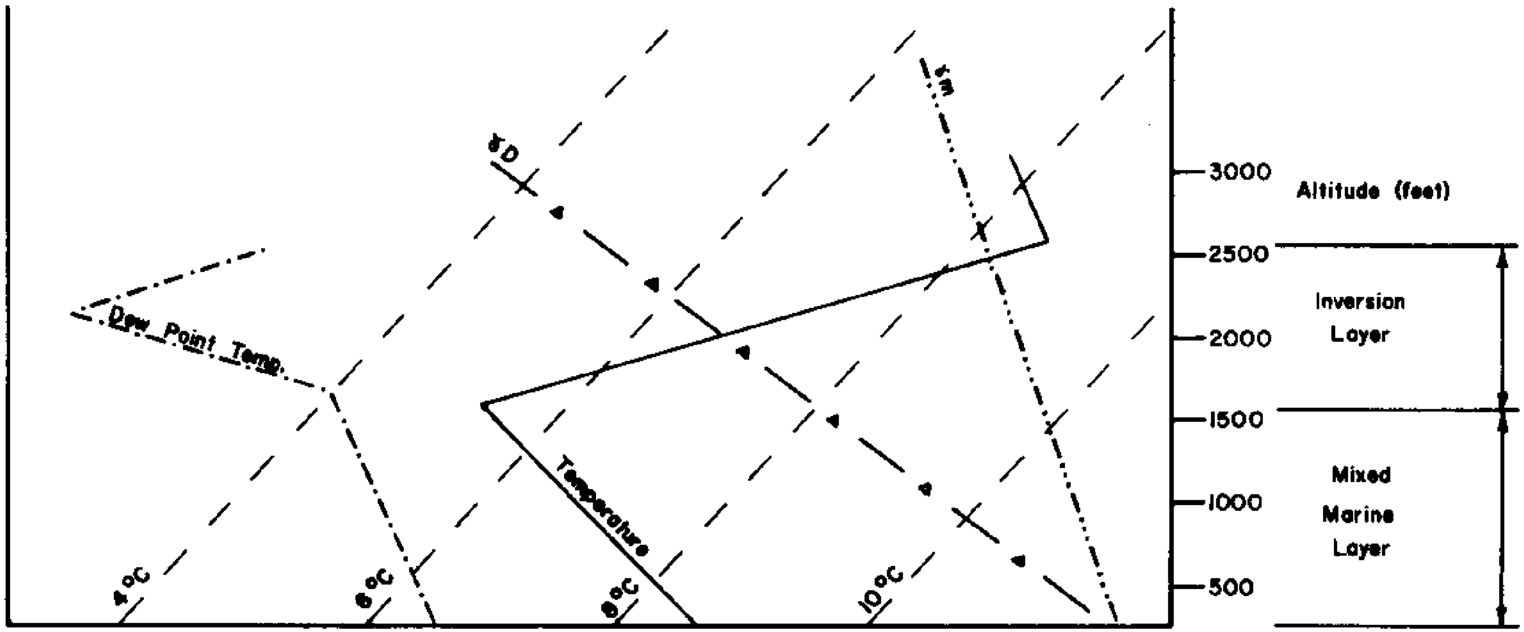
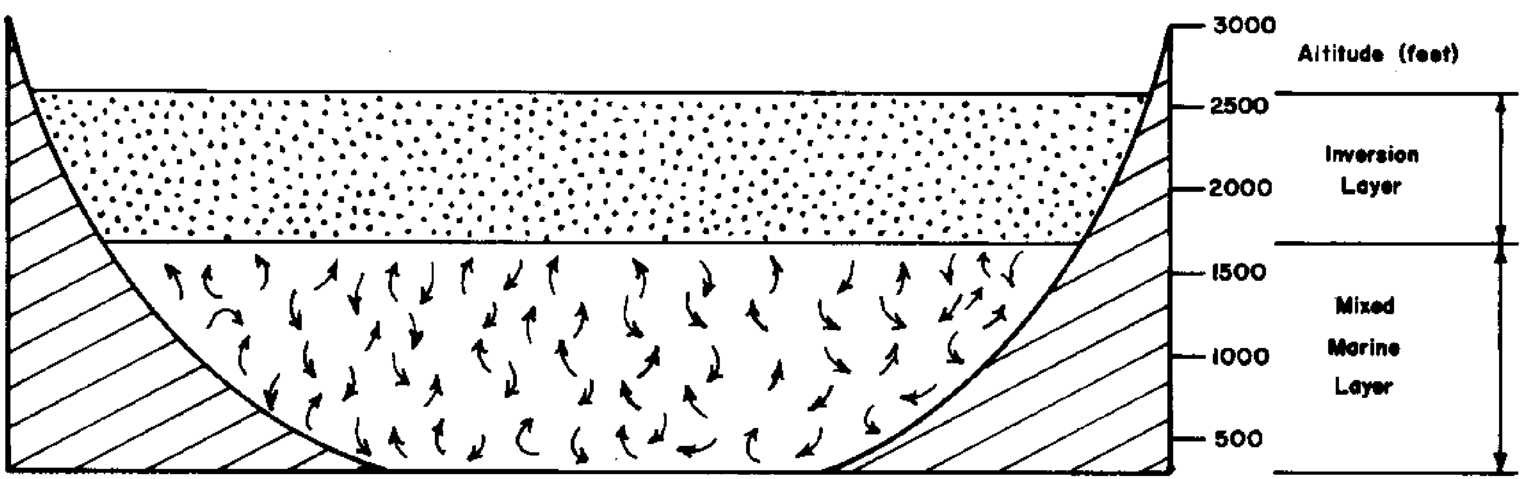


Figure 2. Temperature and dew point temperature vertical profile at Salinas, California with a vertical cross section of the valley showing the mixed marine layer and dry inversion layer.



stability considerations, we can deduce the turbulent mixing as shown in the marine layer and the absence of vertical motion in the inversion layer.

The consequences of the atmospheric and oceanographic conditions in this part of California are such that the offshore low level air flow is often parallel to the coast line and from a prevailing northerly direction and there is a frictional stress placed on surface waters which causes a mass transport of surface waters off the coast and there is a cold upwelling of nutrient rich, and relatively predator free waters from the bottom along the coast line and in the bay. Humid warmer air is found some distance off shore, and in response to the heating differential across the beach interface, flows toward the shore and is cooled from below causing fogs and low stratus clouds which may flood across the beach interface for some distance into the valley. Prior to urbanization, salt and dust particles served as condensation nuclei for the fog and cloud droplets. As urbanization and industrialization progresses, many more hygroscopic nuclei are present in the form of industrial atmospheric waste. Condensation occurs at much lower humidities and the air becomes hazy and smoky long before fog and low clouds form. The air then is dirtier, fog droplets are smaller, and fog density greater.

Observations and Analyses

The wind observations were taken from the Pacific Gas and Electric Plant located on the coast line of Monterey Bay at Moss Landing, California for the period January to December 1971. The wind sensors are located approximately 250 feet above sea level and the wind speeds may be higher and the wind directions different than those taken closer to the surface. Wind analyses made at the Marine Laboratories at Moss Landing indicate that a wind speed maximum is often found at 300 to 600 feet above sea level during the early morning and late afternoon wind soundings.

The wind directions in the analyses are based on 8 points of the compass:

N 360° $\pm$ 22°	S 180° $\pm$ 22°
NE 045 $\pm$ 22°	SW 225° $\pm$ 22°
E 090° $\pm$ 22°	W 270° $\pm$ 22°
SE 135° $\pm$ 22°	NW 315° $\pm$ 22°

The wind direction means very little in the analyses where the wind speeds are 5 mph or less because of the sensitivity of wind sensors at those low wind velocities. In the analyses where speeds are 5 mph or less stagnant conditions are the rule, but where a wind direction seemed to persist at these low wind speeds a direction is indicated. Wind speeds are computed as 3 hour running averages.

Smoothing of wind speed and direction and the classification into categories was done in order to take into account the air flow which takes place at the beach interface throughout the whole period. Wind speeds in the analyses are categorized by stippled areas of dots where the wind speeds are 5 mph or less. Much of this period the wind speeds were appreciably less than 5 mph. In the hatched areas the wind speeds are 15 mph or greater (see Figure 3). There were several periods when wind speeds were 25 mph or greater, but adding another category of wind speed seemed to complicate the analysis. Any wind speed of 15 mph or greater indicates a strong surge of air into the air shed. Clear areas on the analyses indicate winds of 6 mph or more but less than 15 mph. These clear areas in the analyses may be considered as transitions between the periods of stagnation with low ventilation and the periods of strong ventilation. The transition is often between calm or slight southeasterly flow and the stronger afternoon winds from the west.

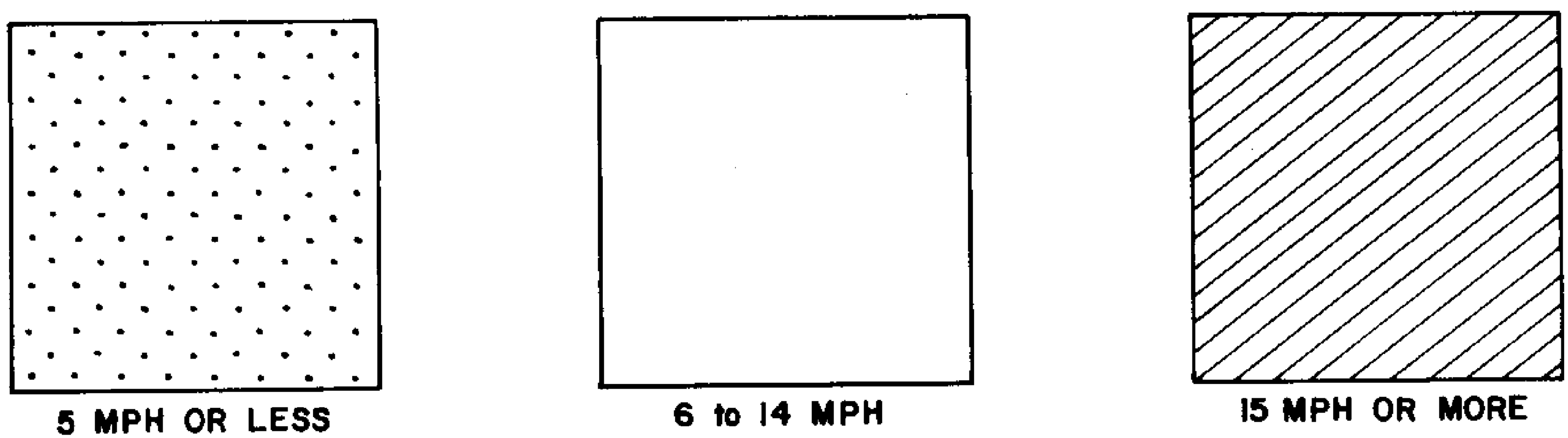


Figure 3. Wind speed legend for use with analyses.

The transition zone may have occurred for only a short period of time but in the averaged smooth analysis it may appear longer. During the summer months the winds rarely rose much above 15 mph.

The analyses are arranged by months with the ordinate being time of day and the abscissa days of the month. No one hour or day of the month is represented exactly as it occurred, but has been blended into the total analysis for the month. Time of day is arranged so that the hours of noon to midnight are in the center of the analyses as most of the air flow across the beach interface occurs during this period. Periods of stagnation will show up much more clearly if the user of the analysis will color in the stippled areas with some appropriate color.

Discussion

The wind flow at the land-sea-air interface of Monterey Bay which was measured at about 250 feet above sea level at the Pacific Gas and Electric Plant at Moss Landing, California is shown in Figures 4 through 15. The analyses seem to show diurnal variations in the amount of air flow across this interface. Stagnant conditions are most prevalent from midnight to noon of the next day. Moderate to strong flow occurs most frequently from noontime to about 2200 with a weakening of the flow until midnight when stagnant conditions actually occur. During the winter months the patterns show strong surges of air throughout the whole day for periods of one or more days followed by periods of stagnation throughout the day for one or more days. December, January, February, March, and the last half of April are periods with strong surges of air flow across the interface. During May there are also some strong surges of the air flow, but the summer time pattern of

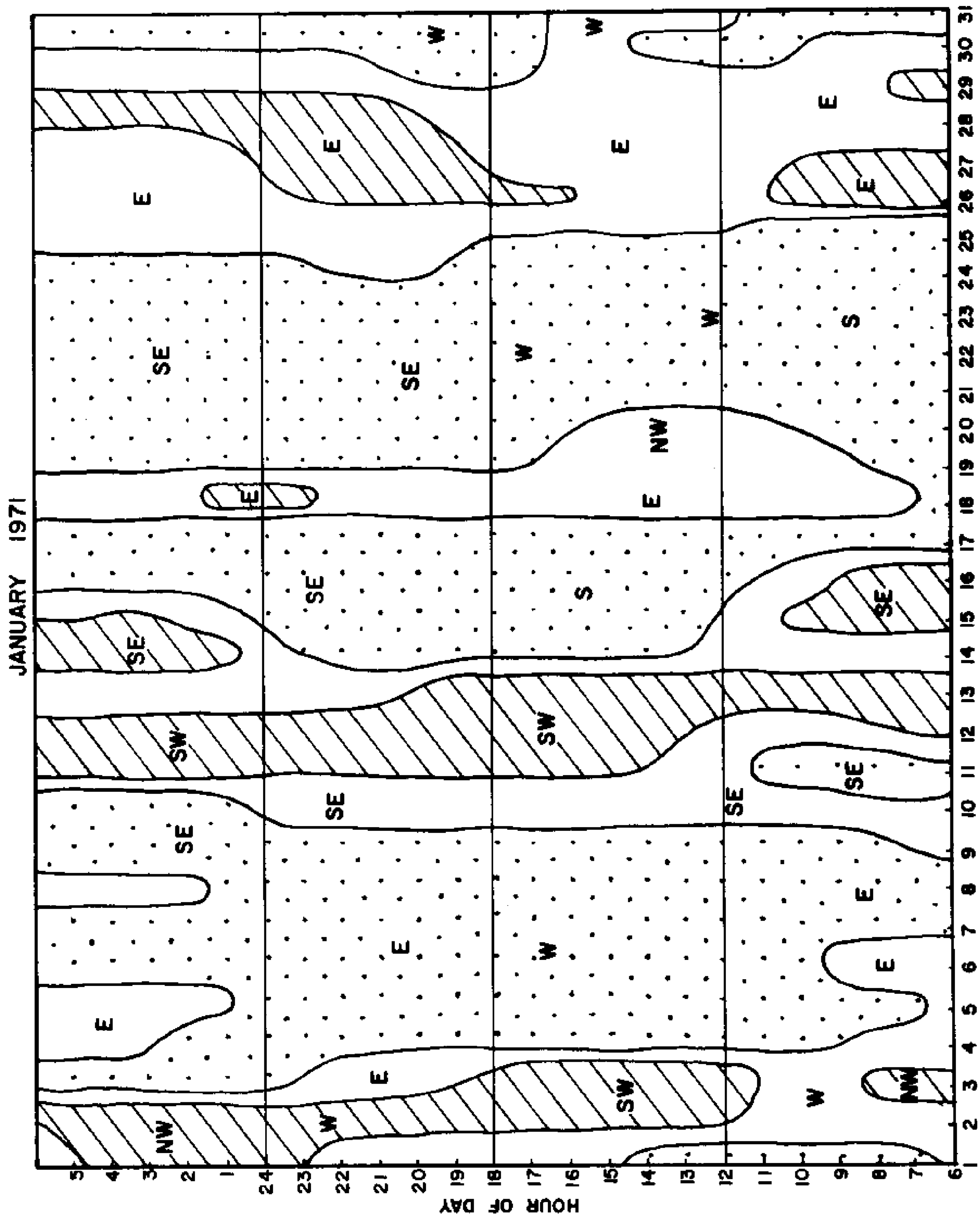


Figure 4. Air flow analysis January 1971.

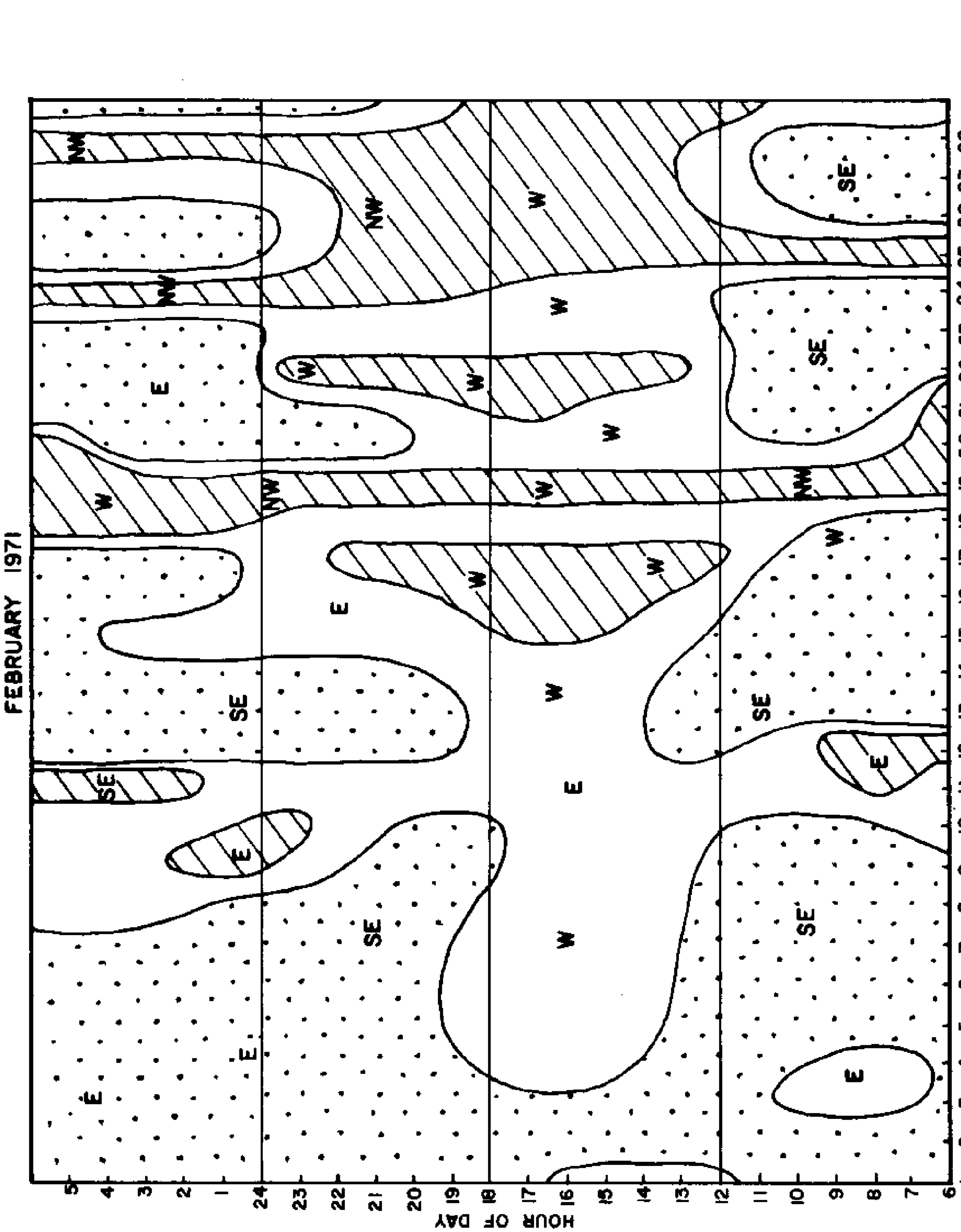


Figure 5. Air flow analysis February 1971.

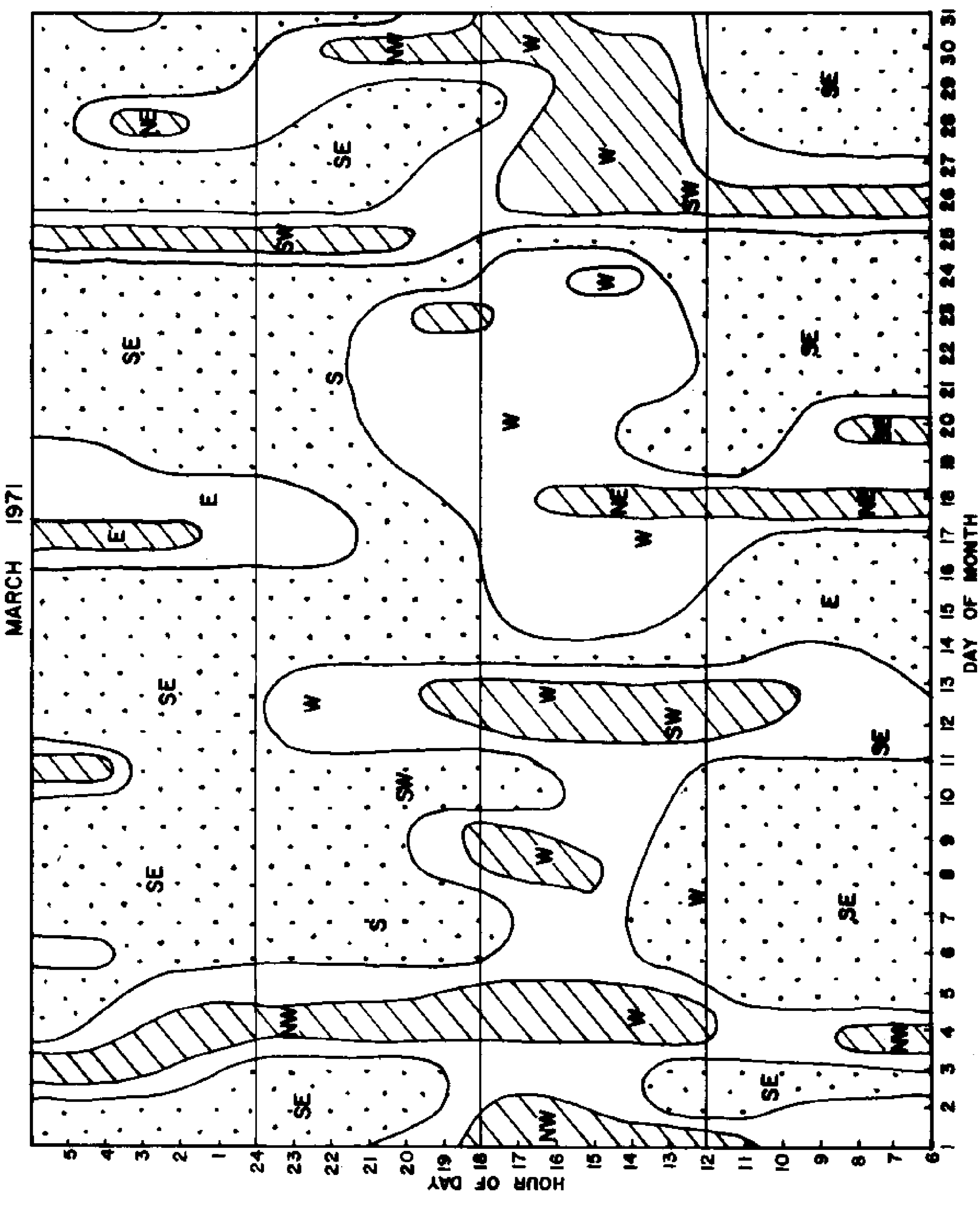


Figure 6. Air flow analysis March 1971.

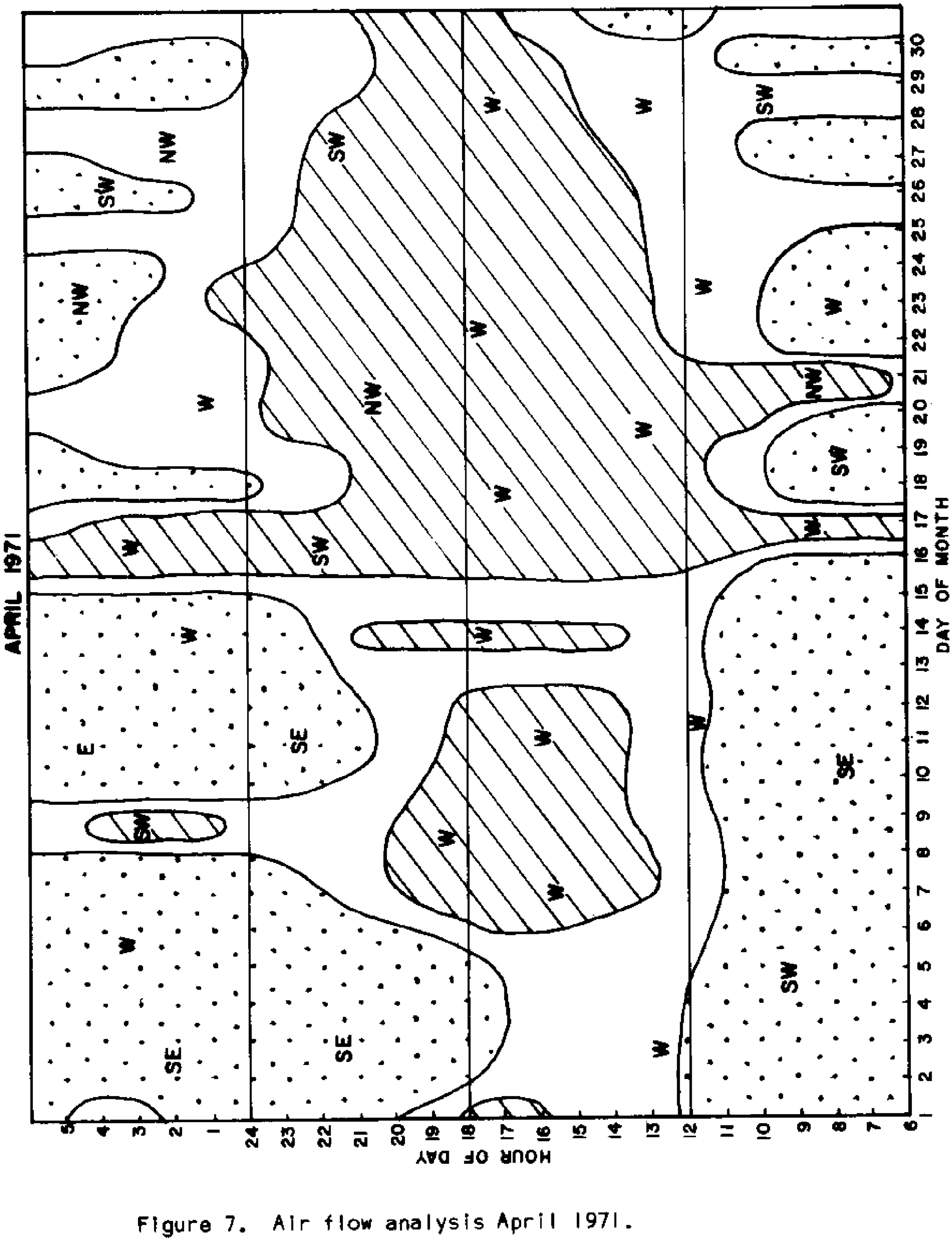


Figure 7. Air flow analysis April 1971.

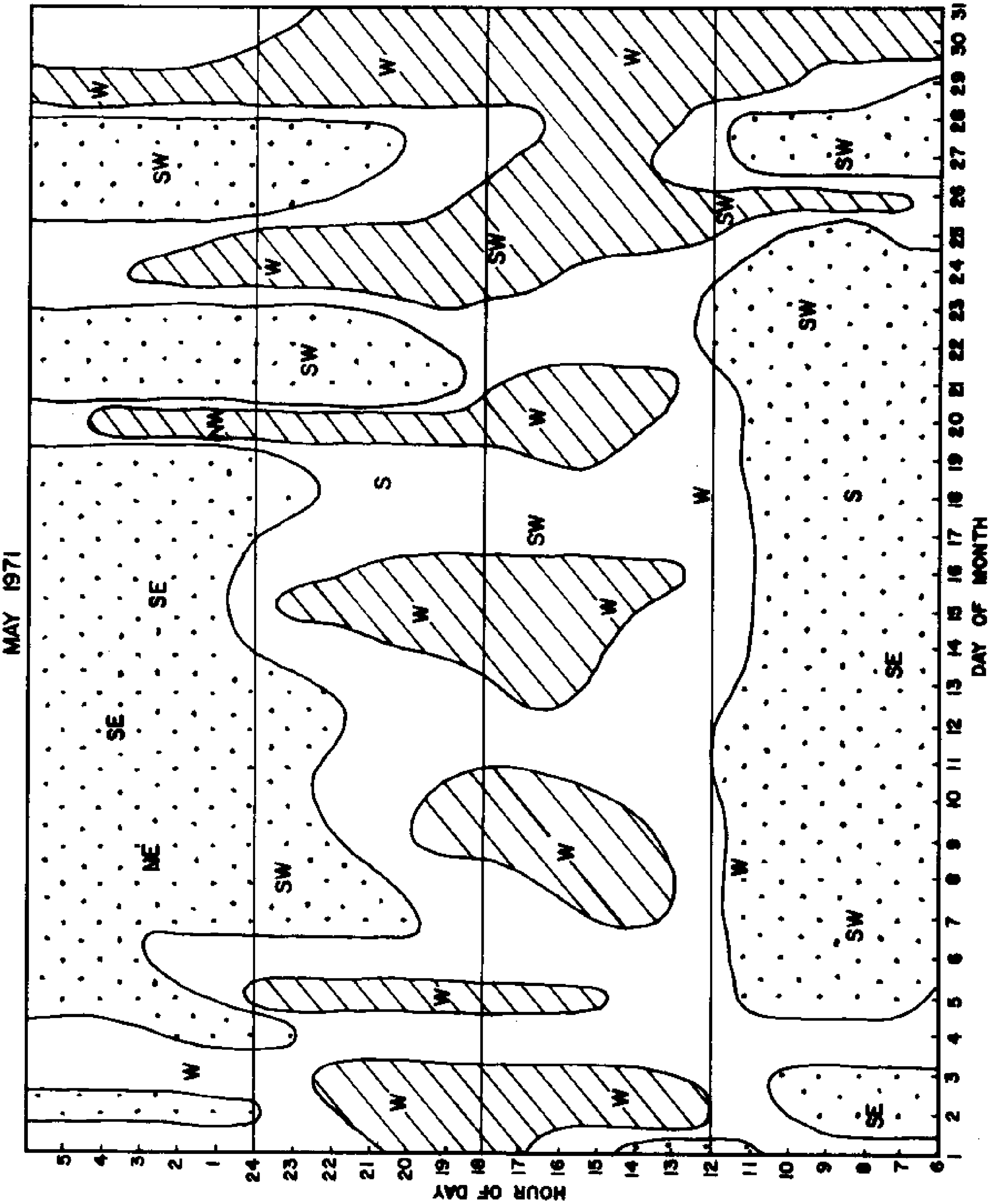


Figure 8. Air flow analysis May 1971.

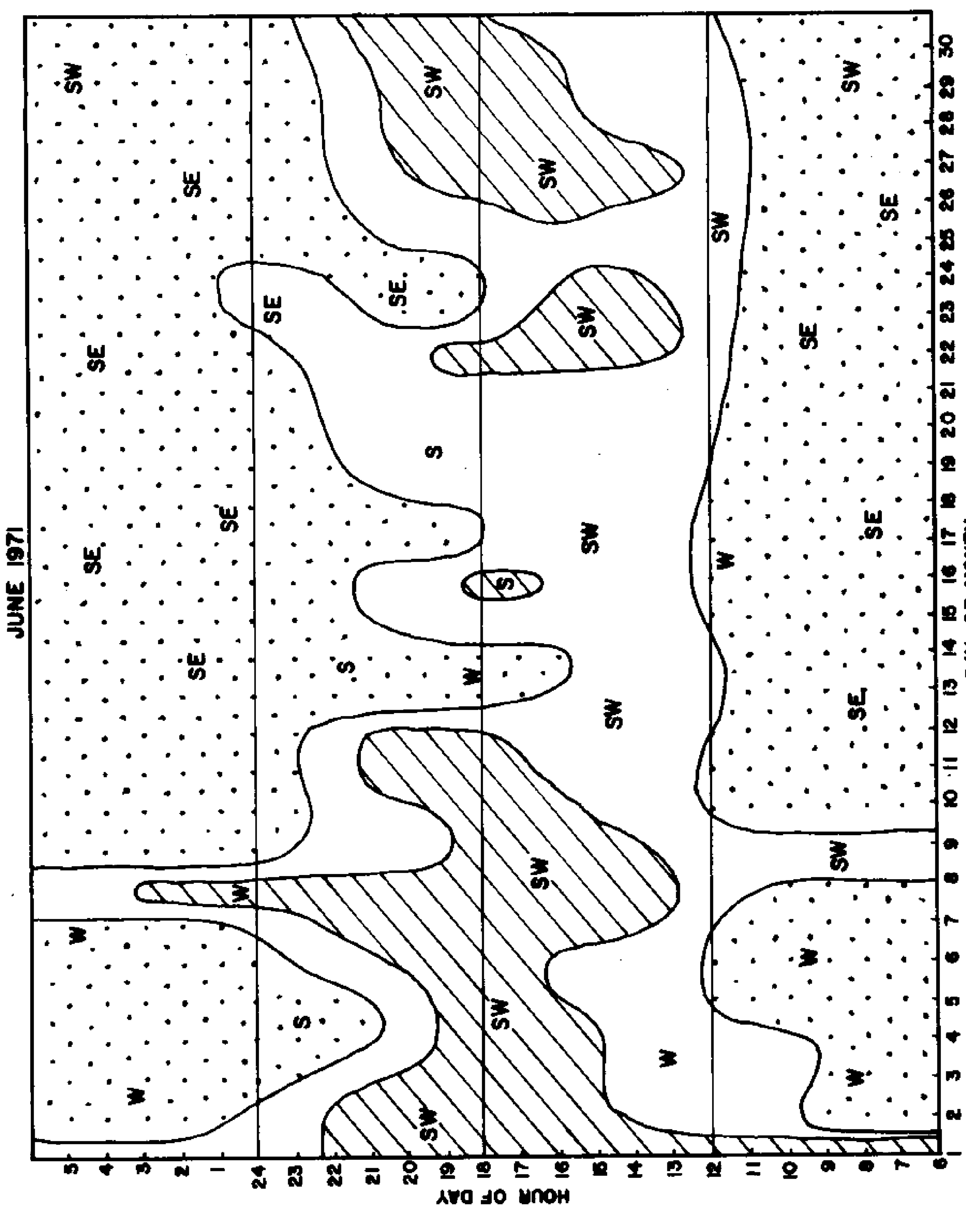


Figure 9. Air flow analysis June 1971.

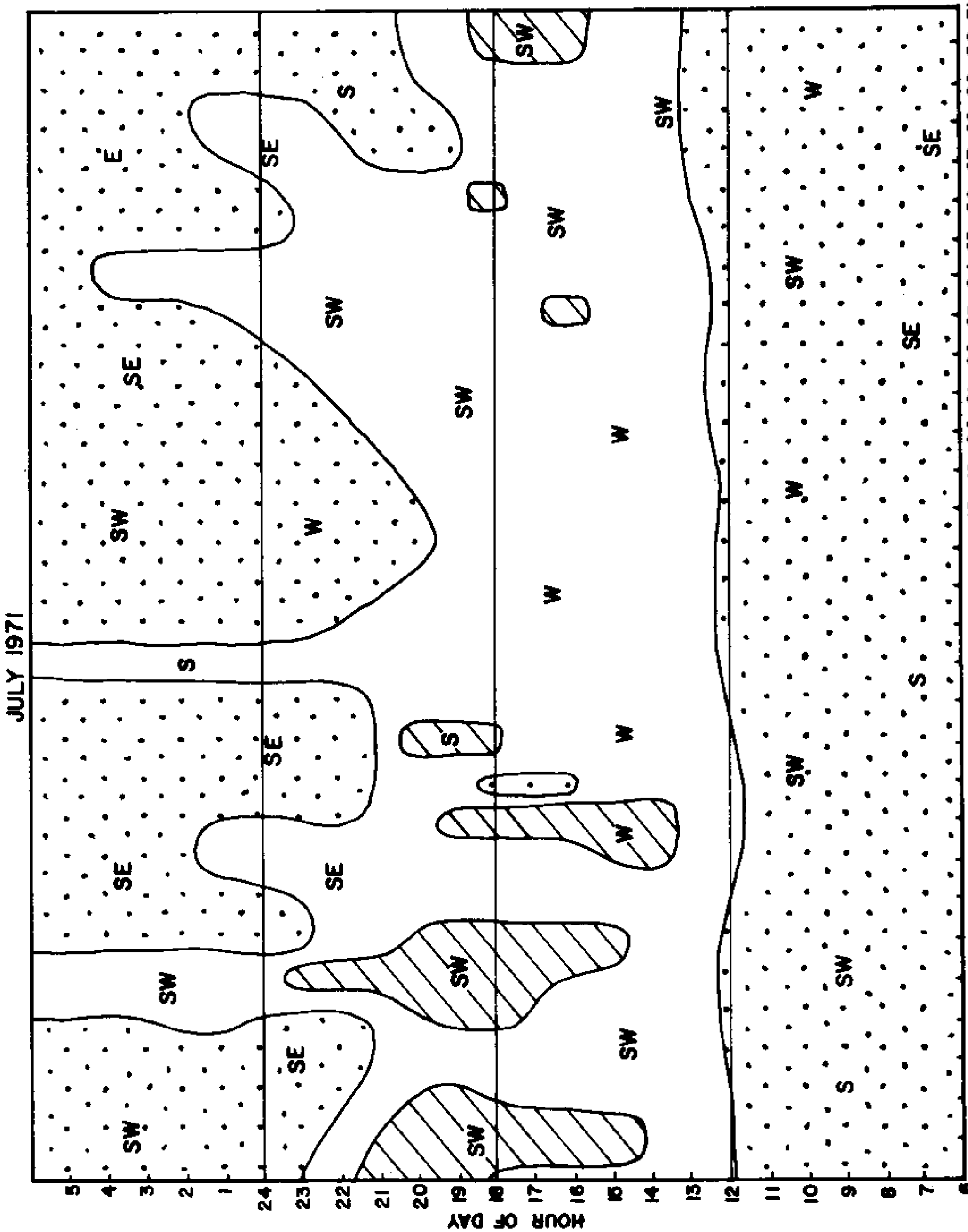


Figure 10. Air flow analysis July 1971.

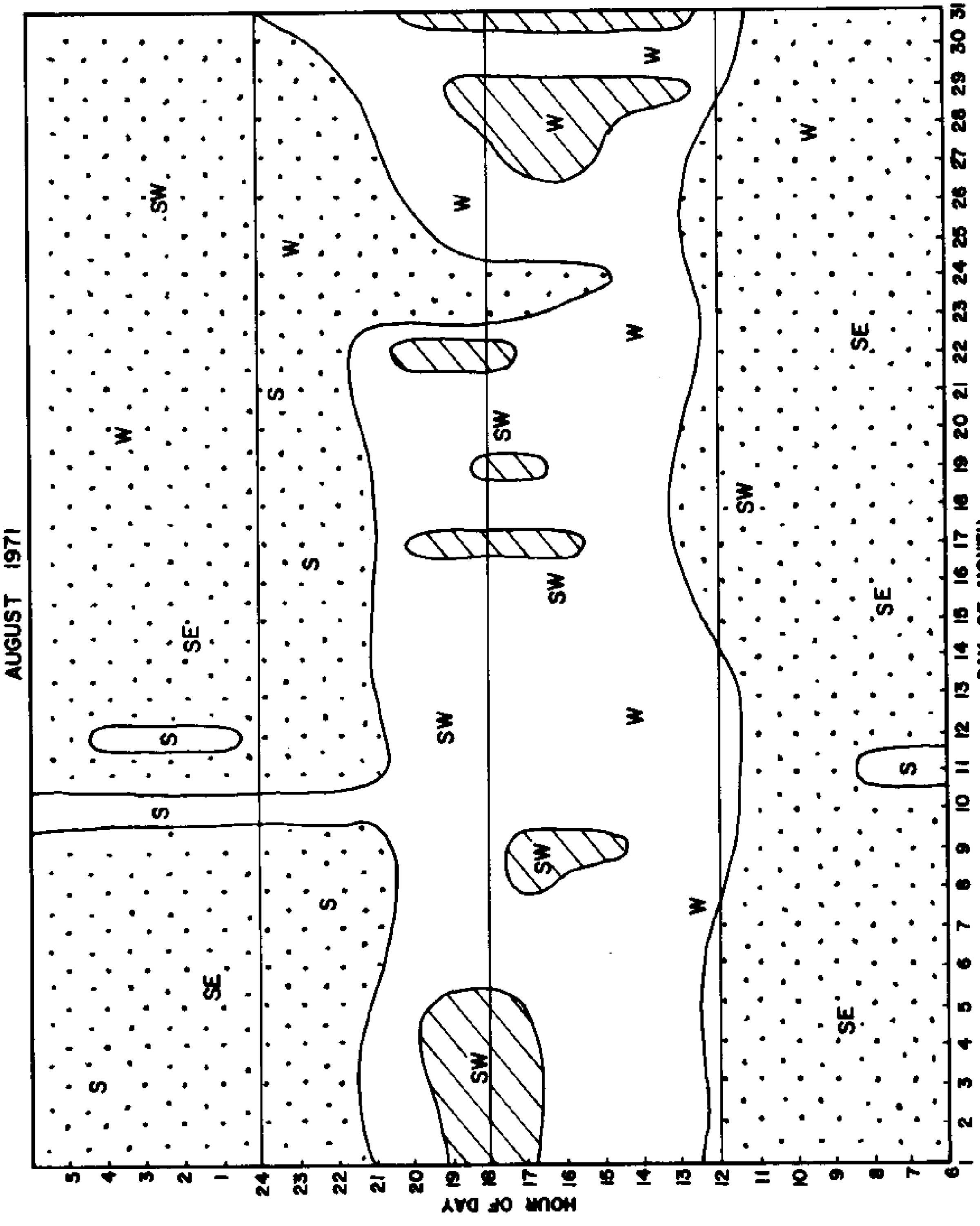


Figure 11. Air flow analysis August 1971.

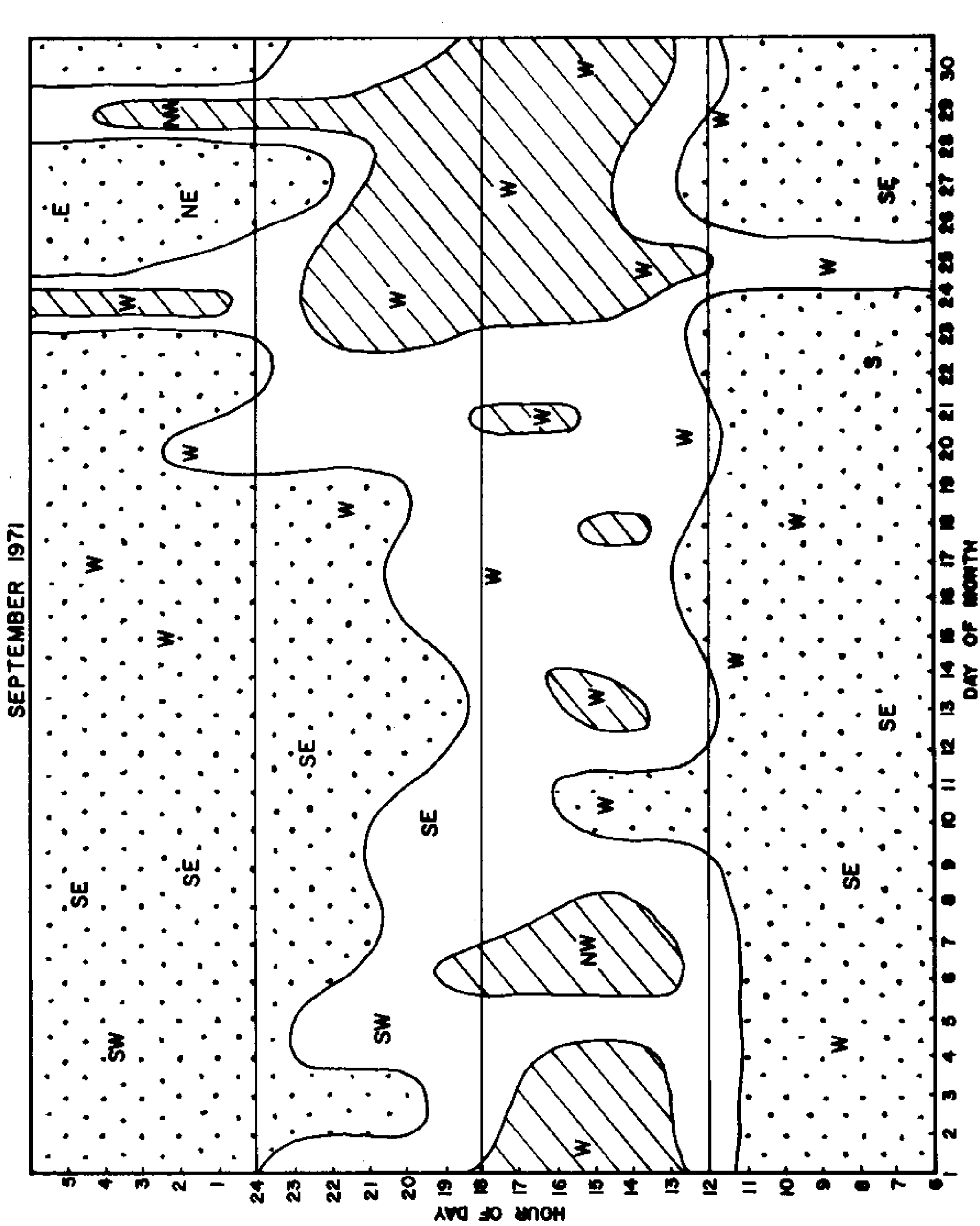


Figure 12. Air flow analysis September 1971.

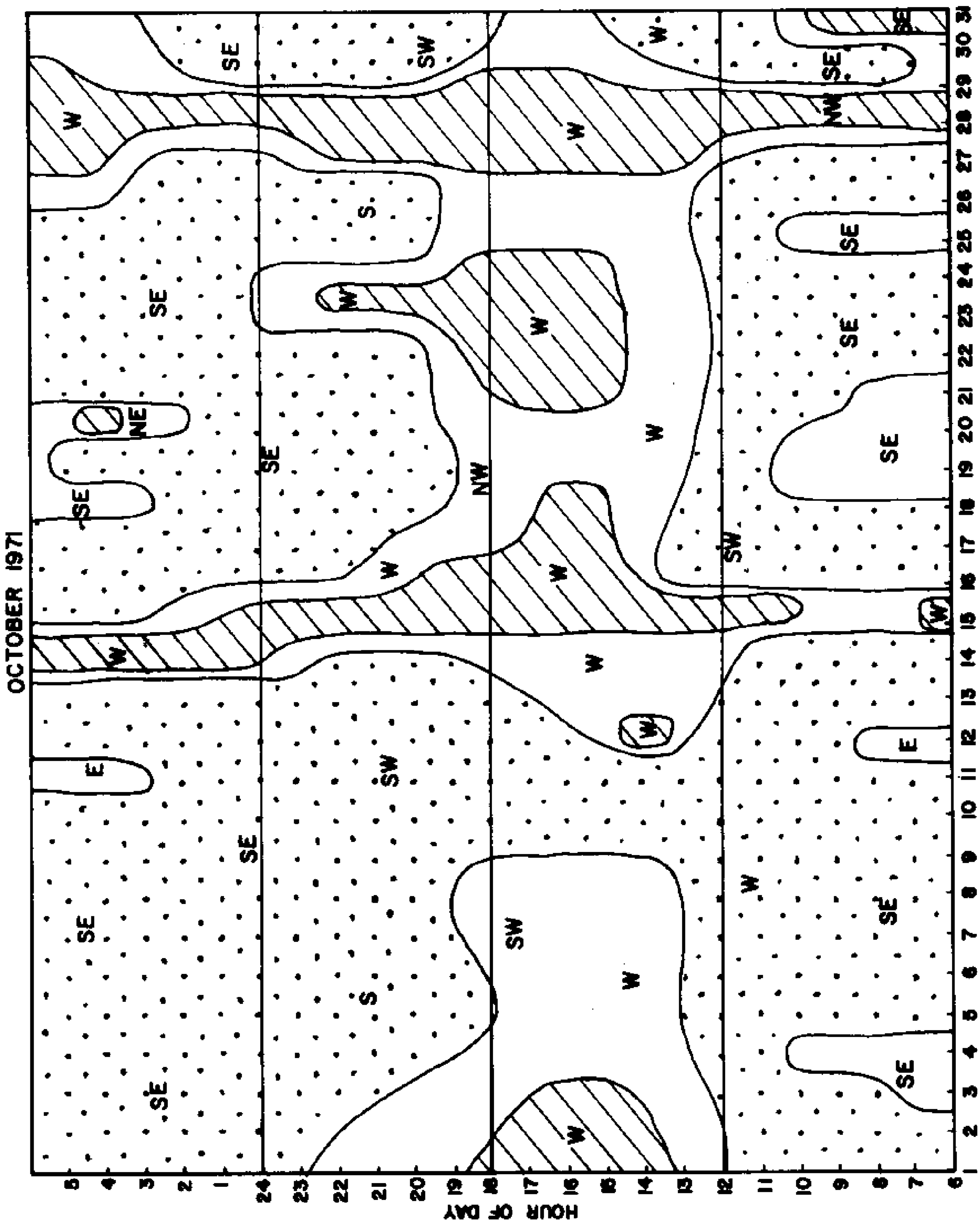


Figure 13. Air flow analysis October 1971.

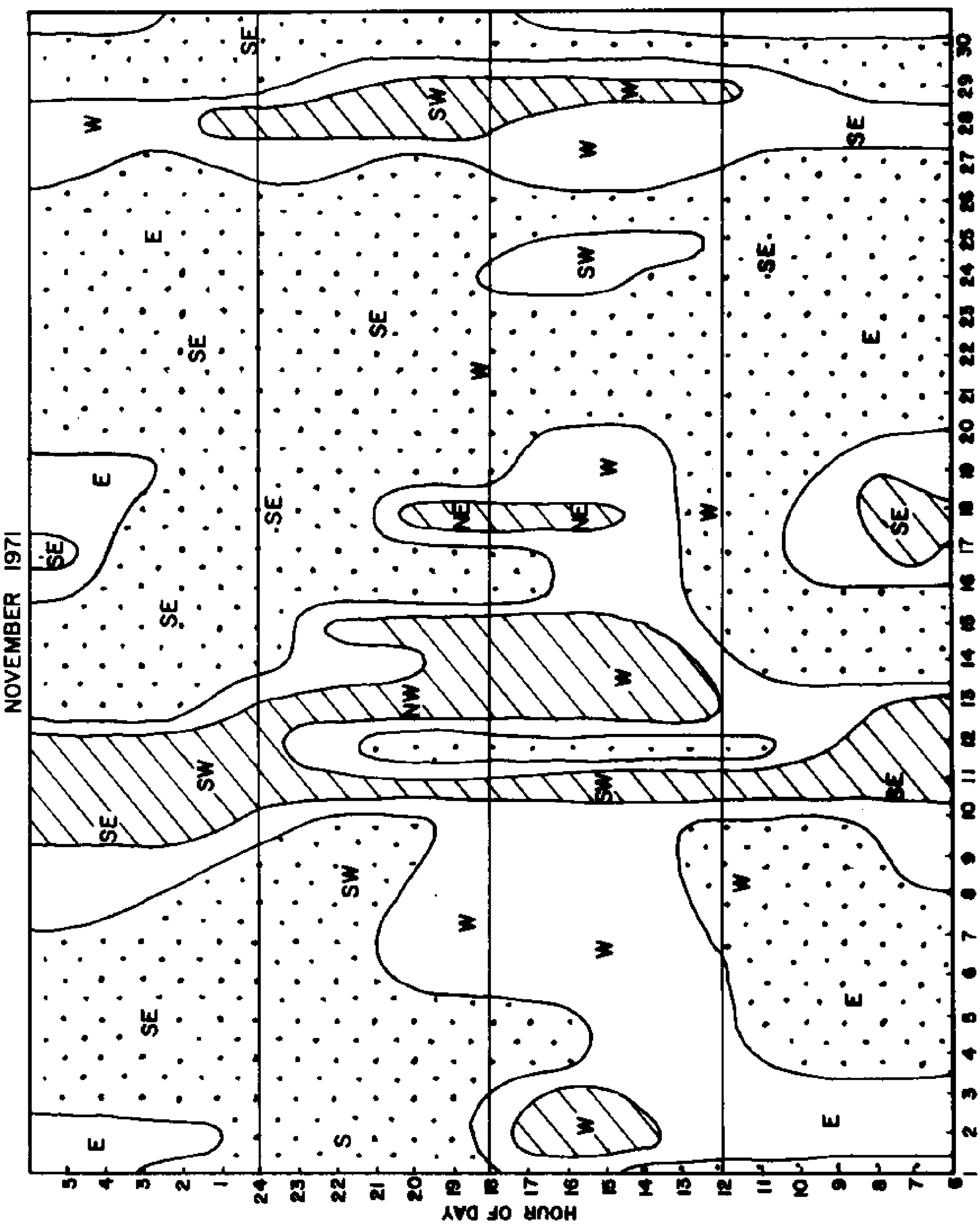


Figure 14. Air flow analysis November 1971.

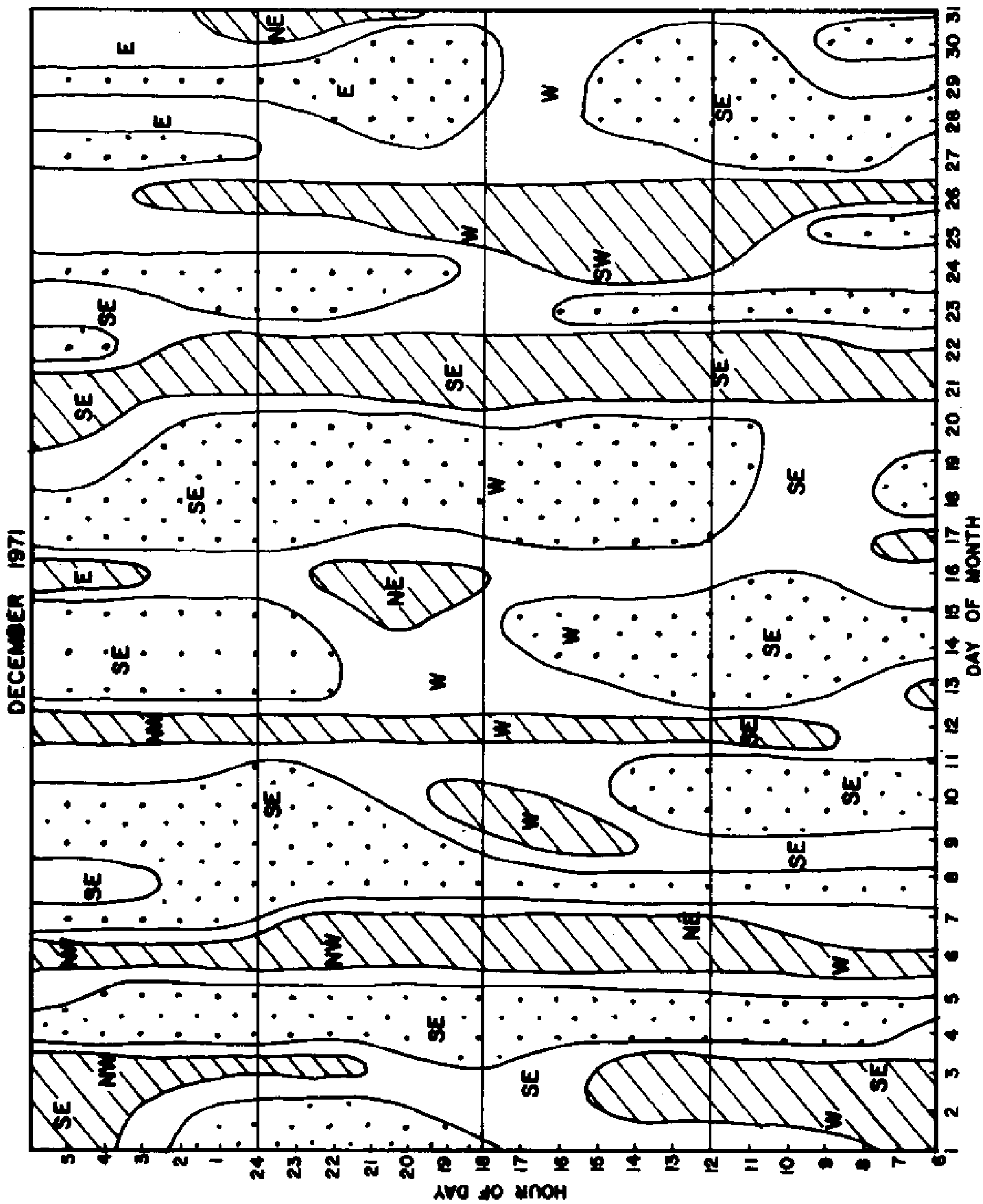


Figure 15. Air flow analysis December 1971.

stagnation during the period midnight to noon appears to be setting in. In June, July, August, and September, the pattern seems to be stagnation from midnight to noon with moderate air flow across the interface from noon to 2200. October and November appear to be transition periods. While the pattern of stagnation occurs as in the summer months, there are strong surges of air flow which last all day for one or more days. Both October and November have periods when stagnation occurs throughout the day.

Throughout the year whenever the flow is greater than 5 mph, the prevailing wind direction at the land-sea-air interface is from a westerly direction. This means that the primary air flow is marine air moving on shore and into the Salinas Valley. There are some short periods of time when there is strong flow from an easterly direction or towards the bay during the winter months. The periods of strong flow from the east usually last for only a few hours and rarely persist through the whole day.

Conclusions and Recommendations

Intelligent planning for the urbanization or industrialization of the coastal areas of Monterey Bay and the Salinas Valley depends upon an understanding of the atmospheric conditions which lead to trapping and dispersal of atmospheric waste which is a concomitant of such development. Workable solutions to industrial problems of air pollution and zoning restrictions for plant location of heavy industry moving into the area on the basis of realistic atmospheric models must be explored.

The analyses of the wind flow at the beach interface during the year 1971 shows onshore flow of marine air throughout the year when wind speeds are in excess of 5 mph. During a large part of the year there appears to be an inversion caused by the turbulent wind mixing in the marine layer or a subsidence inversion caused by subsiding columns of air in the North Pacific High Pressure Cell with the inversion base lower at the coast than it is inland, Read (1971). The coastal areas and the seaward extent of the Salinas Valley are rapidly becoming urbanized, yet this is the region where atmospheric conditions most effectively trap atmospheric waste close to the ground. In view of these atmospheric conditions, specific zoning to minimize industrialization and high density urbanization in these areas must be placed into effect as soon as possible. Without some action of this nature, the same smog, fading blue skies, poor visibilities, and respiratory problems of the Los Angeles and Santa Clara Valleys must be contended with here. Well planned urban living areas can be placed on the more gentle slopes of the valley where day time atmospheric conditions may vent pollutants out of the air shed. Some additional industrial plants may move into the area, but these plants should be located where the atmospheric conditions maximize dilution and dispersion of atmospheric waste products. This would call for plant location some twenty to sixty miles inland from the coast. During long periods of the year there appears to be a diurnal pattern of stagnation during the hours midnight to noon of the following day. While it is realized that there is a public air pollution syndrome present in the area that resents visible plumes from industrial plants which are quite apparent during daylight hours, it still remains that the hours from noon to 2200 are in the period when maximum ventilation occurs. Fog or smog will persist for longer periods of time when there is little ventilation or air flow across the beach interface and into the valley. It is the atmospheric conditions that determine the path taken by and the dilution of these pollutant. It should be realized that during periods of sparkling weather the pollution sources remain about the same as they are on a smoggy day, but the difference is found in the stability of the atmosphere. For example, how strong is the air flow, and to what depth is mixing taking place. Thus, there are certain times of the day and seasons of the year when the atmosphere is prone to accumulate pollutants and other times when the atmospheric waste products are efficiently dispersed. For any given wind speed and time period there is a prescribed volume of air into which a pollution source may inject pollutants. If you double the wind speed, you double the volume and as a consequence halve the pollutant concentration. Edinger (1971) gives the analog of a constant flow of liquid sewage into a stagnant pond, a slow moving river, and a fast moving river. Both the transport and dilution increase with increasing current speeds.

These analyses may also prove helpful in making plans for fishing and boating operations in the coastal waters of Monterey Bay. The summer diurnal patterns indicate time periods when little flow and consequent wind wave and current development may be expected. Although there is a time differential between daily maximum surface winds at the coast and at stations further inland in the valley, these analyses should prove helpful in determining seasonal agricultural burning in the valley. The patterns of stagnation and ventilation while not exactly the same year to year may be expected to be close enough to permit first estimates in situations such as those discussed here.

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