AN ABSTRACT OF THE THESIS OF

Boris R. Pavelka for the M. S. in Meteorology
(Name) (Degree) (Major)

Date thesis is presented ______________

Title SOME EFFECTS OF METEOROLOGICAL PROCESSES ON THE AIR QUALITY IN MEDFORD, OREGON

Abstract approved [redacted]
(Major professor)

In Medford, Oregon, the major source of pollution is the lumber mill waste burner. Its low combustion efficiency results in the emission of large quantities of particulate into the atmosphere.

Due to the influence of the atmospheric radiation inversion and possibly the poor performance of the burners at the time of start-up, concentrations of particulate were found to be highest in the morning. Correlating these morning concentrations with average surface relative humidity, average surface wind speed, and various stability indices, most of which were determined from the U. S. Weather Bureau's 0300 PST radiosonde release, provided a measure of the degree of relationship between these meteorological factors and pollution. In addition, the analysis resulted in a determination of what stability factors could readily be used to predict pollution concentrations with reasonable accuracy (correlation coefficients $\geq 0.65$). These included the sounding energy to 850 mb (energy required to lift a parcel

of air from surface to 850 mb), the temperature difference index (difference in temperature between 850 mb and surface), the Modified Showalter Stability Index (Showalter Index applied to the layer of air between surface and 850 mb), and the persistence index (the sum of three weighted Modified Showalter Index values for three consecutive mornings).

Graphical and regression prediction models involving the persistence index and average surface wind speed were developed. These relationships proved to be more accurate in predicting morning concentrations of particulate (multiple correlation coefficients $\geq 0.84$) than those involving only one meteorological variable (highest correlation coefficient $\doteq 0.74$).

In order to illustrate the effects of air pollution on visibility, a preliminary relationship between concentrations of suspended particulate and visibility was developed. If visibility were selected as the criterion for judging air quality as it might well be in a tourist-oriented economy, such a relationship could serve as the basis for forecasting conditions of unacceptably low visibility as a result of high concentrations.

# SOME EFFECTS OF METEOROLOGICAL PROCESSES ON THE AIR QUALITY IN MEDFORD, OREGON

by

BORIS R. PAVELKA

A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1966

APPROVED:

[redacted]

Assistant Professor of Biometeorology

In Charge of Major

[redacted]

Head of Department of Physics

[redacted]

Dean of Graduate School

Date thesis is presented July 2, 1965

Typed by Marion F. Palmateer

ACKNOWLEDGMENTS

I wish to express my gratefulness for the unselfish cooperation of Dr. William Lowry, assistant professor biometeorology, and Dr. Richard Boubel, associate professor of mechanical engineering, both of Oregon State University. With their assistance, the writing of this thesis proved to be an enjoyable experience.

My deepest gratitude to the people in Medford, Oregon, who kindly assisted the Medford Air Pollution Project of 1964 by providing information or collecting data, such as the personnel of the United States Weather Bureau, the Oregon State Sanitary Authority, the Oregon State University Agricultural Extension Center, the Jackson County Planning Commission, and the managers of the Thunderbird Lodge. The effort they expended contributed greatly to the success of the project.

To my fellow students James McElroy, Bruce Meland, and Paul Willison, whose advice on meteorological problems proved to be invaluable, and to Larry Janssen, Stanley Kirk, and William Maki, whose skill at computer programming resulted in rapid evaluation of the data: the best of luck in the future!

For her admirable patience while I struggled through the writing of this thesis, I wish to express my appreciation to my fiancee, Miss Claudia Larsen.

I extend my thanks to the United States Public Health Service for supporting my research and graduate studies during the school year of 1964-1965.

B. P.

TABLE OF CONTENTS

## LIST OF FIGURES

LIST OF TABLES

# SOME EFFECTS OF METEOROLOGICAL PROCESSES ON THE AIR QUALITY IN MEDFORD, OREGON

## INTRODUCTION

During the summer of 1964, the Engineering Experiment Station of Oregon State University conducted a study of the air pollution problem created by lumber mill waste burners in Medford, Oregon. The project was under the leadership of Dr. Richard Boubel, associate professor of mechanical engineering at Oregon State. The author had the privilege of working as the Experiment Station's representative in the Medford area.

The project had several objectives, the most important of which were: (1) to make recommendations to the mills on how the efficiency of the burners could be improved, (2) to analyze the feasibility of hauling the waste to a highly efficient, centralized burner or of using this waste to generate power, and (3) to measure the air quality in Medford and determine how the meteorology of the area influences pollution concentrations.

To underscore the magnitude of the waste burner problem, it should be noted that the teepee waste burner is a very poor combustion chamber, emitting at least 22 pounds of particulate per ton of material burned (3, p. 50). According to a 1962 estimate (5), 4500 tons of residue were being produced in Jackson and Josephine

Counties in one day, enough to fill a line of train cars over two miles long. When this estimate was made, more than 2600 tons were burned in the two counties, of which at least 1742 tons were burned in the Medford-White City area. As a result of the Medford Project of 1964, it has been estimated this latter amount has risen to 1856 tons per day (3, p. 20).

The result of burning wood residue in Medford is that approximately 78 percent of the suspended particulate in the atmosphere comes from the burners (3, p. 22). When intense radiation inversions occur, notably during the fall and winter months, concentrations of 150 $\mu$-grams/$m^3$ or greater are occasionally measured in residential areas.[1]

To compound the problem of heavy pollution from inefficient burners, Medford has the potentiality for pollution problems on a geophysical basis alone. The city is located in the center of a small but deep valley.[2] Downward transfer of horizontal momentum from upper air flow is thereby hindered, resulting in low wind speeds within the valley (14, p. 7). Radiation inversions in turn are rather

---

[1]The Oregon State Sanitary Authority has established 150 $\mu$-grams/$m^3$ above normal background as the maximum allowable level of suspended particulate in residential and commercial areas (14, Part II, p. 17).

[2]Medford is located in the Bear Creek Valley, which has an area of approximately 144 square miles. Mountains rise two to three thousand feet above the valley floor six miles from the center of the city.

intense because low wind speeds cannot destroy these stable air regimes. Pictorially speaking, then, Medford is located in a closed box, the sides of which are the mountains, the invisible top of which is the inversion. In a situation such as this neither horizontal nor vertical dispersal of pollutants is very effective.

In order to improve the combustion efficiency of burners, some research has been conducted on auxiliary gas-fired systems.[3] On a burner of reasonable efficiency, such a system would not have to be operated continuously. In fact, the cost of continuous operation would probably prove to be prohibitive to most mills. This thesis suggests that accurate short-range forecasts of pollution potential are possible at Medford, and that they could be used to decide on which days intermittent gas-firing would be most beneficial in the face of adverse environmental conditions. At least one successful precedent for using meteorological forecast in this way was established in 1941 when the lead-zinc smelter at Trail, British Columbia, began using forecasts to prevent sulfur dioxide damage to crops in its vicinity (20, p. 28).

Many citizens of Medford are concerned about the damaging effect of pollution on the aesthetic appeal of the area, and thereby on a

---

[3]The organization conducting research on auxiliary gas-fired systems prefers to remain anonymous.

rapidly growing tourist trade (1). During the summer, a voluntary agreement by the lumber industry to operate below a maximum pollution concentration dictated by visibility considerations would be likely to alleviate this problem. Indications are (see page 43) that such a standard would be more stringent than the present legal standard, but short-term operation of auxiliary gas-fired systems at times determined by meteorological forecasts would probably make the adjustment economically feasible.

# OBJECTIVES

In determining the objectives of this thesis, the following two factors were taken into consideration: (1) that a determination of the effects of meteorological processes on the air quality in Medford, Oregon, was a project objective (see page 1) and (2) that an operational forecast procedure for pollution concentrations might aid in solving Medford's air pollution problem.

Correlating concentrations of suspended particulate with various meteorological variables was selected as the first objective. The variables for these correlations were chosen for at least one of the following reasons: (1) to illustrate the effects of meteorological processes on air quality; (2) to determine the prediction potential of these variables, either by themselves or as terms in a multivariate prediction model.

On the assumption that multivariate prediction models would have a greater prediction accuracy than a single meteorological variable, the second objective chosen was to develop such models. The results of the preliminary correlations would be used as a guide for determining the variables for these models.

Determining a useful relationship between concentrations of suspended particulate and visibility was selected as the third objective. If visibility were selected as a criterion for judging air quality, as suggested above, such a relationship could serve as the basis for forecasting a condition of unacceptable low visibility when used in conjunction with the techniques to be developed in pursuing the second objective.

# PROCEDURE

In order to measure the air quality in the Medford area (3, p.17), sampling stations were established at the following sites: (1) the Jackson County Court House, which is located in the center of the city, (2) the Medford Municipal Airport, which is located three miles north of the city center, and (3) the Oregon State University Agricultural Extension Center, which is located two miles southeast of the city center (see Appendix, page 62). Each station was equipped with a High Volume Air Sampler, or Hi-Vol as it is commonly called (3, p. 13). In addition, the airport and court house stations were provided with tape samplers in order to measure soiling intensity (3, p.14).

Since tape sampling, which was based on two hour sampling periods, was initiated several weeks before any samples were collected with the Hi-Vols, an analysis of the tapes provided the first indication that in Medford, as in other cities (2, p. 130), the highest concentrations of pollution occur in the morning (3, p. 28). When the Hi-Vols became available, the personnel of the U.S. Weather Bureau generously agreed to take three eight-hour samples a day instead of the usual 24-hour sample (6, 13, 15, 19). In this way, gross diurnal variations in concentrations of suspended particulate could be readily detected. Of equal importance with regard to developing a forecast procedure was the fact that the effect on air quality of a meteorological phenomenon occurring only at a certain time of the day, such as the radiation inversion, could probably be measured more accurately with an eight-hour sample than with a 24-hour sample.

The Hi-Vol data presented in Figure 1 show that the mean concentrations of suspended particulate are higher in the morning than in the afternoon or evening. The same was indicated by the tape samplers. However, as one would expect, not all individual days followed this pattern. This becomes evident by comparing the three maximum or minimum pollution concentrations of each day of the week for the sampling period of August 23 through October 31.

Before the first sample was collected with the Hi-Vols, the results of tape sampling and of visual observations beginning about July 1 seemed to indicate that the radiation inversion was the primary meteorological cause of high pollution concentrations in the morning (3, p. 26) as well as an important influence on air quality at other times of the day. On the basis of this indication, the author decided to confine his attention to the morning sampling period and to emphasize the analysis of the stability of the lower atmosphere. Inversions based above the surface were not considered at all since their effect on surface concentrations of suspended particulate was undoubtedly small. In any case, only five such inversions occurred during the sampling period of August 23 through October 31(see Appendix,

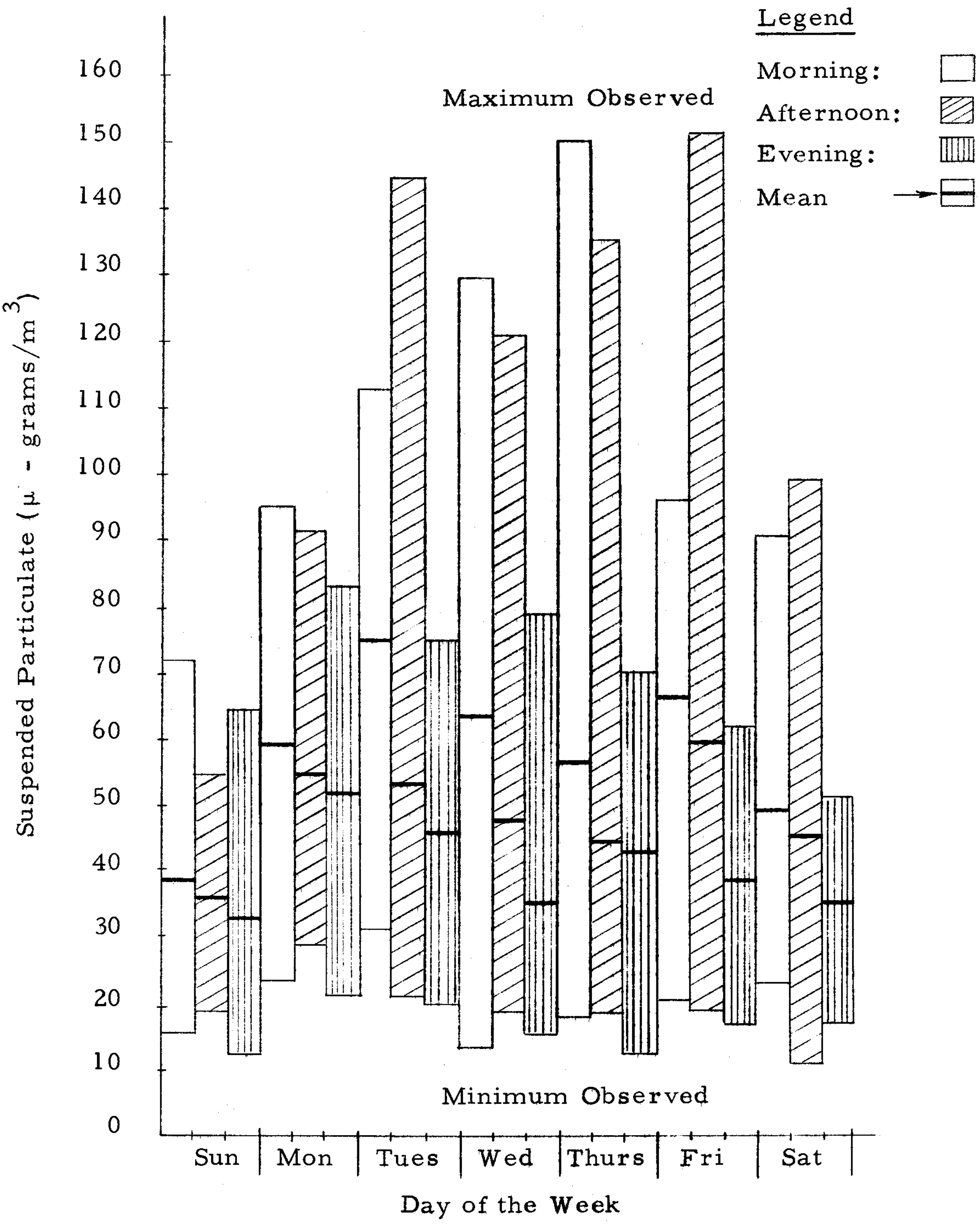



Figure 1. Distributions of Morning (0330-1130 PST), Afternoon (1130-1930 PST), and Evening (1930-0330 PST) Concentrations of Suspended Particulate for the Sampling Period of August 23, 1964, through October 31, 1964 (Medford Municipal Airport).

page 55), and a superficial review of the soundings on these days indicated that their intensity was not great.

The morning Hi-Vol sample was scheduled for the time period of 0330 to 1130 PST, chosen so as to encompass the peak pollution period of the morning, which occurred between 0500 and 0900 PST (3, p. 28). Another reason for this scheduling was the fact that the U. S. Weather Bureau released a radiosonde at 0300 PST each day, and the data from these soundings would undoubtedly be of great importance in correlations involving morning concentrations of suspended particulate. Afternoon and evening sampling periods were scheduled around the morning sample (1130-1930 and 1930-0330 PST).

Since many lumber mills are not in operation on Saturday and probably none are in operation on Sunday, a decrease in the mean concentrations of pollution from work week (Monday through Friday) through weekend occurs (see Table 1). As a result, Saturday and Sunday data were not included in any of the preliminary correlations or used in the development of multivariate prediction models.

Table 1. A Comparison of Work Week and Weekend Concentrations of Suspended Particulate for the Sampling Period of August 23, 1964, through October 31, 1964 (Medford Municipal Airport).

| | Work Week | Saturday | Sunday |
|---|---|---|---|
| Morning | 63. 8 | 49. 7 | 39. 1 |
| Afternoon | 52. 5 | 45. 0 | 37. 2 |
| Evening | 43. 4 | 36. 9 | 30. 4 |

In order to facilitate the graphical presentation of all the relationships involving suspended particulate and a single meteorological variable, Monday and Friday were selected as a representative sample of the days of the work week. All simple correlation coefficients, designated by R, and equations of the lines that best fit the data were determined from this sample.

In developing multivariate prediction models, all work week data were included, except for observation 33 (see Appendix, page 56), which proved to be damaged, and seven randomly selected samples, which were set aside to serve as test data (see Appendix, page 55). These excluded samples constituted approximately 20 percent of the data used to develop the models.

Several types of parameter were used to express the degree of correlation in the prediction models and in the relationship between suspended particulate and visibility. A multiple correlation coefficient was expressed as the absolute value of R, or $|R|$. A correlation between observed and predicted values was designated by r. The average deviation of test data, that is, the average difference between the predicted and the observed, was given by $\pm$ d.

# CORRELATIONS INVOLVING A SINGLE METEOROLOGICAL VARIABLE

## Morning Suspended Particulate as a Function of Temperature Thickness of the Inversion

The temperature thickness of the inversion was determined by subtracting the temperature at the top of the inversion from the temperature at the surface. In all analyses reported here, the top of the inversion was arbitrarily chosen as the lowest level in the atmosphere where isothermal or non-inversion conditions were indicated by the sounding.

Figure 2 illustrates the correlation of suspended particulate with temperature thickness of the inversion. Since the correlation resulted in a value of 0.546, only marginal success could be expected by using this graph for providing early morning forecasts of particulate concentration.

## Morning Suspended Particulate as a Function of a Temperature Difference Index

The temperature difference index was determined by taking the difference in temperature between 850 mb and the surface. (Williams employed a similar index with success (19)). In this study, the standard atmospheric altitude of 850 mb was chosen as the upper

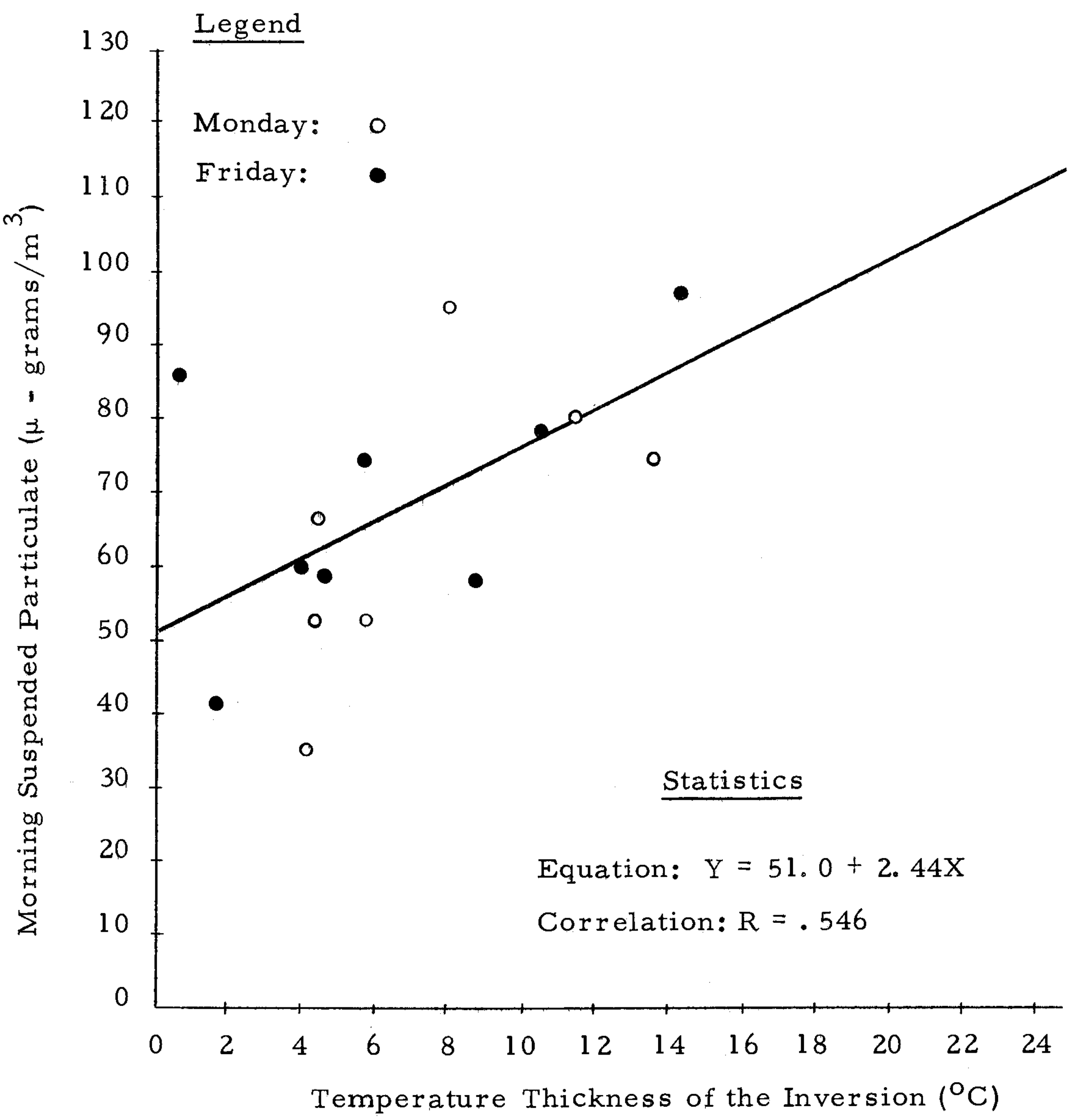



Figure 2. Morning Suspended Particulate as a Function of Temperature Thickness of the Inversion ($\Delta T$ between the Top of the Inversion and the Surface).

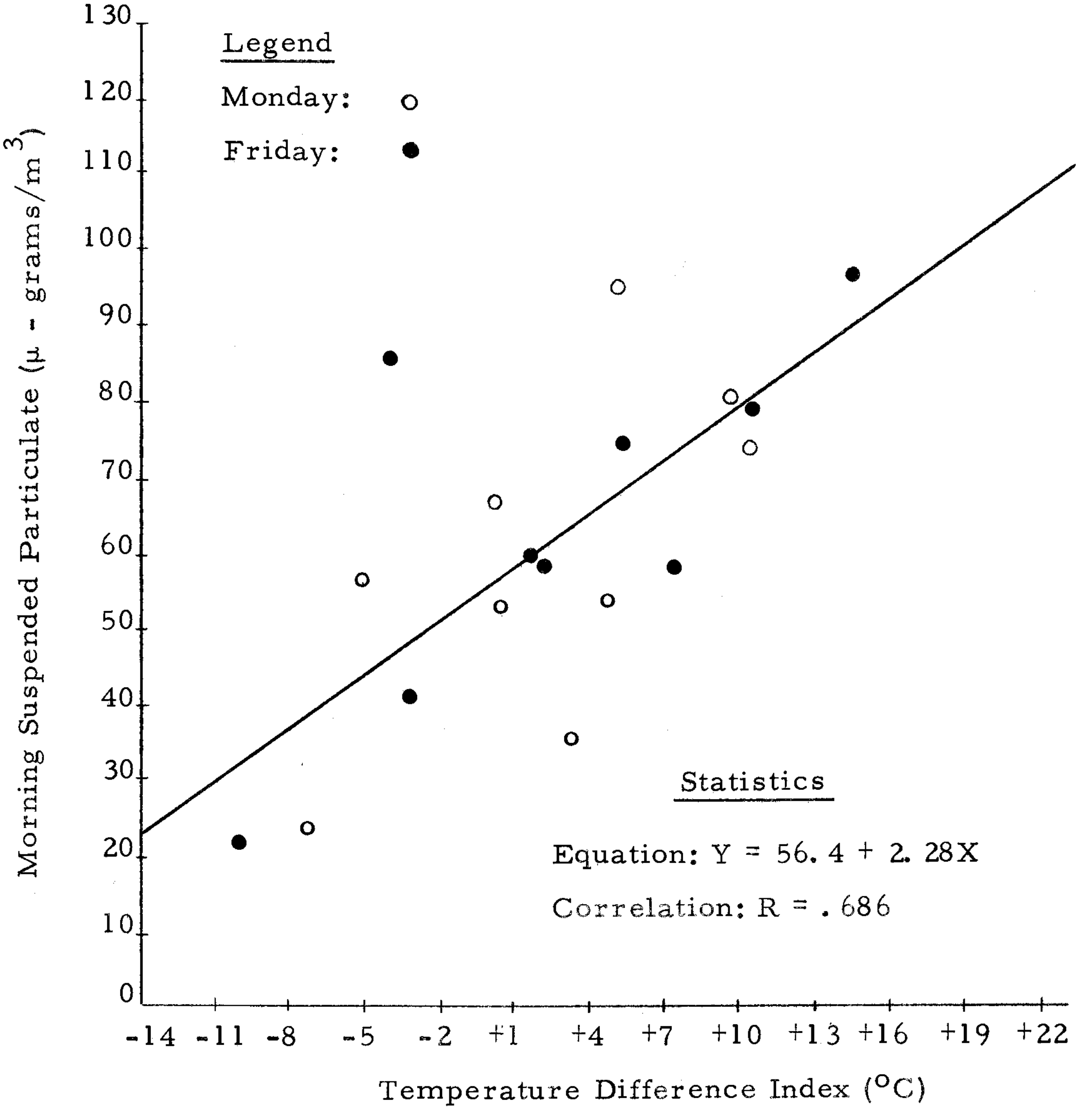



Figure 3. Morning Suspended Particulate as a Function of a Temperature Difference Index (ΔT between 850 mb and the Surface).

boundary of the surface layer of air because most of the energy of the inversion regimes was concentrated below this level (see page 28).

The temperature difference index can be applied to both inversion and non-inversion soundings. The very positive values on the abscissa of Figure 3 indicate inversion conditions; a value of approximately minus 12 indicates a dry adiabatic lapse rate. Acceptance of a relationship having a correlation of at least $\pm$ 0.650 as being reasonably accurate would permit this graph being used to predict morning concentrations of suspended particulate.

## Morning Suspended Particulate as a Function of Morning Temperature Range

In Figure 4, morning suspended particulate is presented as a function of the morning temperature range, calculated by taking the difference between the maximum and the minimum temperatures occurring between 0700 and 1100 PST. On the assumptions that the rate of heat input remained approximately constant on mornings having inversion conditions and that heating on mornings of neutral stability or instability would result in a small temperature change, the temperature range was adopted as a measure of stability available from surface observations alone. The time interval in the definition was selected in such a way as to illustrate the effects of stability on the period of the morning of heaviest industrial activity. The resulting

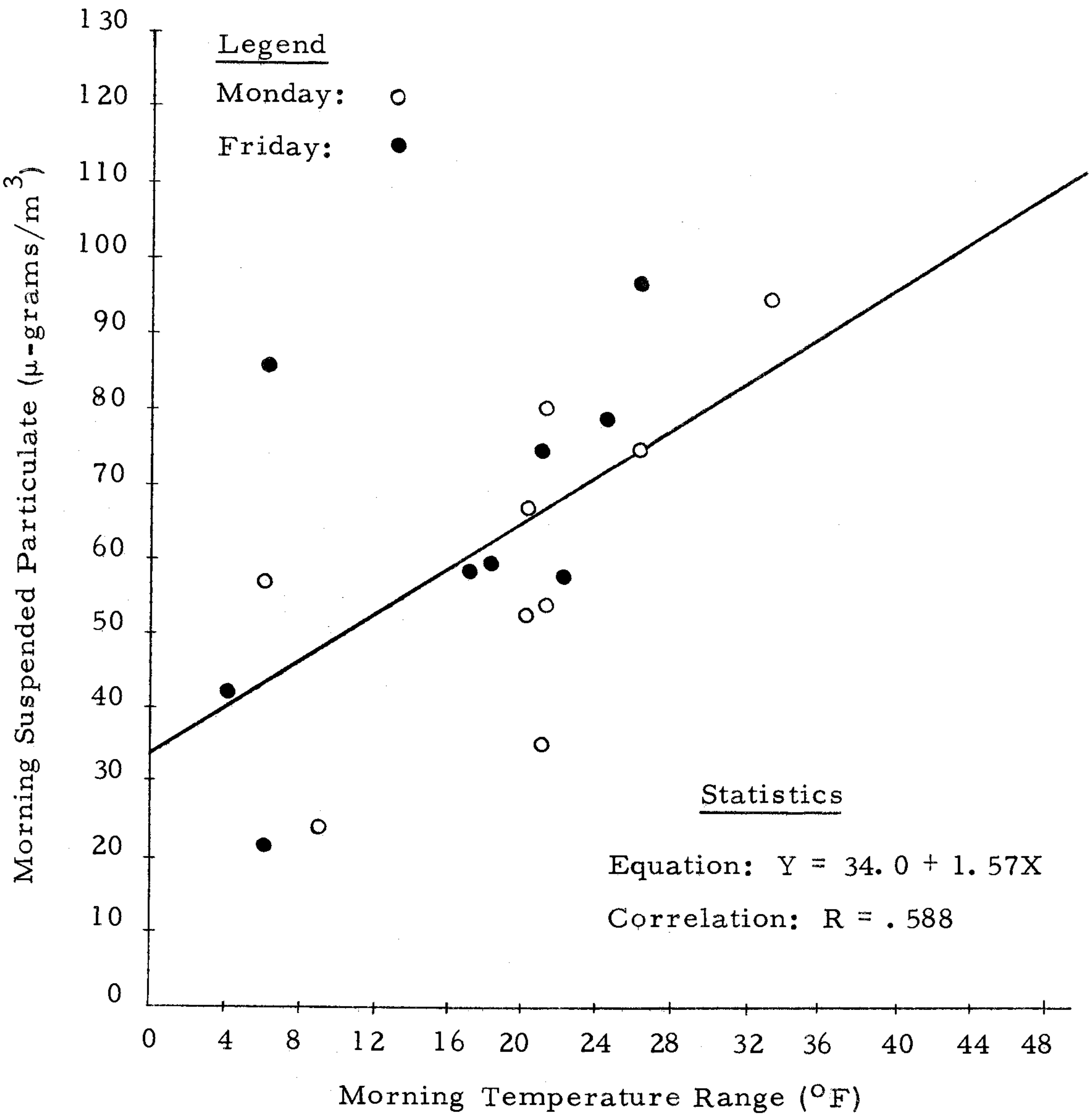



Figure 4. Morning Suspended Particulate as a Function of Morning Temperature Range.

correlation was marginal (R = 0. 588). As a matter of interest, Baynton devised a multivariate model in which a diurnal temperature range was used as one of the factors of a thermal index (2).

Morning Suspended Particulate as a Function of Maximum Mixing Depth

A concept currently popular with air pollution engineers is that of the maximum mixing depth (4), which has recently been discussed thoroughly by Holzworth (9). In the physical basis for the concept, the lower atmosphere is assumed to be heated by convection from below. From a sounding depicting vertical temperature distribution when solar heating begins, one may estimate the depth of maximum convective mixing by noting the pressure level or altitude at which the sounding is intersected by the dry adiabat associated with the maximum surface temperature for the time interval for which this depth is to be estimated (8, p. 38). The dimension of this layer is designated the maximum mixing depth.

The analysis was confined to only those mornings when inversions appeared on the 0330 PST sounding (see Figure 5). Other cases were not considered in order to more nearly restrict the analysis to conditions of true stagnation and low wind speeds. The correlation between suspended particulate and maximum mixing depth was only marginal (R = - 0. 493); however, as one would expect, it did indicate

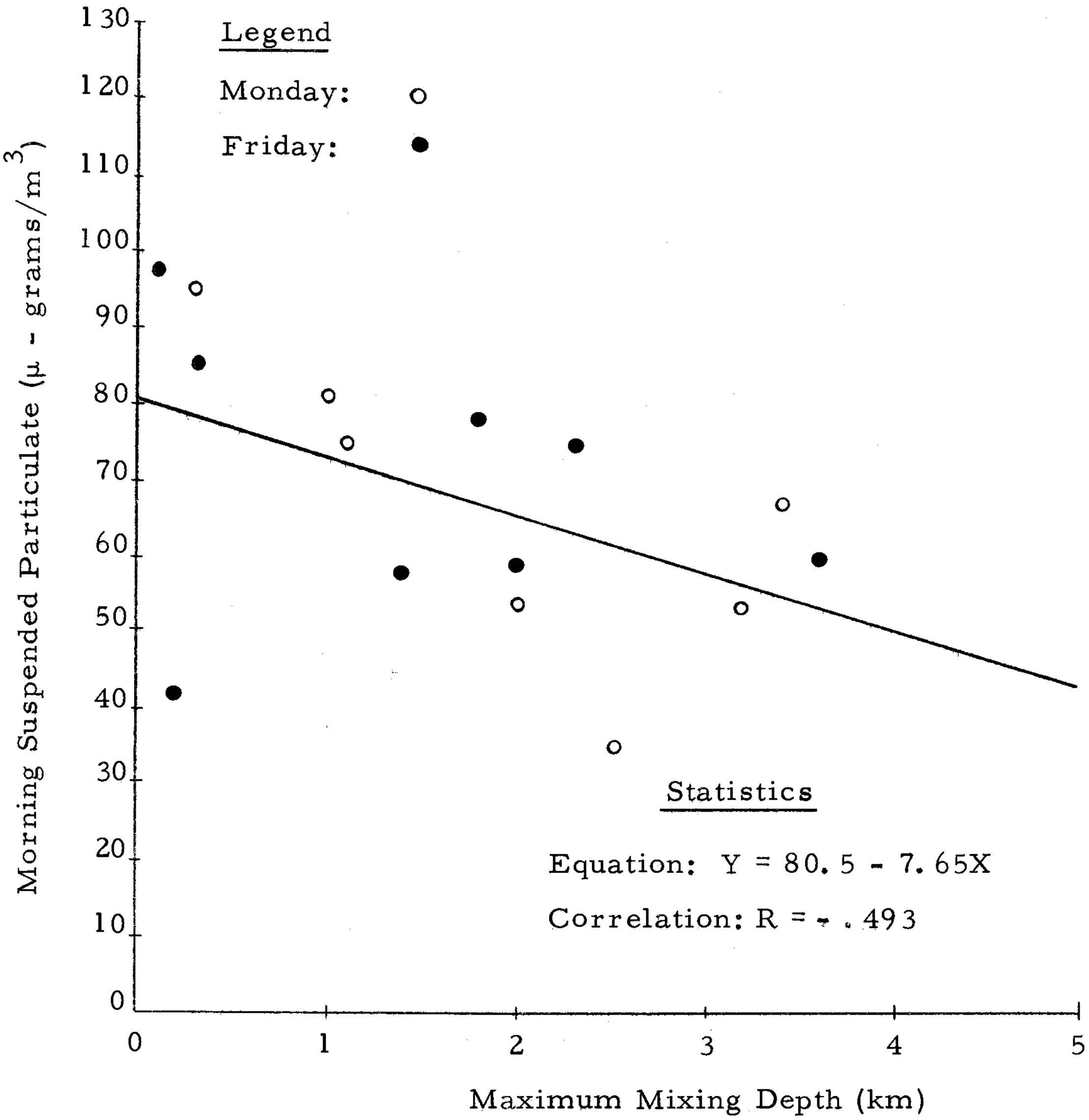



Figure 5. Morning Suspended Particulate as a Function of Maximum Mixing Depth (Inversion Cases Only).

that these two variables are inversely related. As in the previous correlation, 0700 to 1100 PST was chosen as the time interval whose maximum surface temperature determined the maximum mixing depth.

Morning Suspended Particulate as a Function of the Modified Stanford Index

In order to predict pollution potential of subsidence inversions in Los Angeles, the following formula has been proposed:

$$I = \frac{(\Delta\theta)^2}{Z \Delta Z},$$

where:

$I$ = pollution potential,

$\Delta\theta$ = potential temperature difference through the inversion (inversion thickness),

$\Delta Z$ = depth of the inversion, and

$Z$ = height of the inversion base (17).

Among certain research meteorologists, this relationship has become known as the Stanford Index.

Since radiation inversions dealt with here are surface based inversions, the following equation is used to eliminate division by zero:

$$I = \frac{(\Delta\theta)^2}{\Delta Z}$$

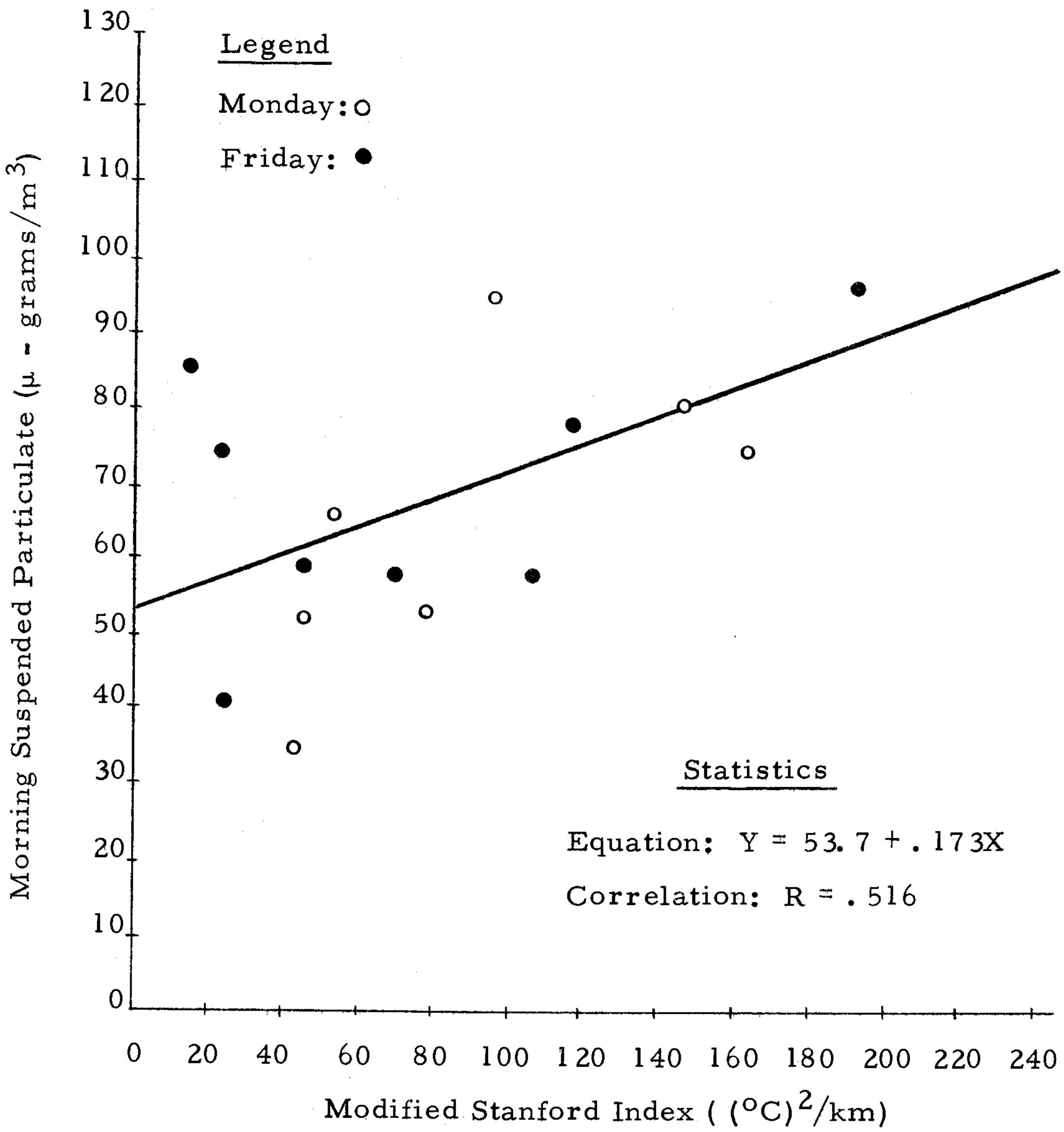



Figure 6. Suspended Particulate as a Function of the Modified Stanford Index $( I = \frac{(\Delta\theta)^2}{\Delta Z} )$

Figure 6 illustrates the correlation of suspended particulate with this Modified Stanford Index.

## Morning Suspended Particulate as a Function of the Showalter Stability Index

A common measure of stability used by the U. S. Weather Bureau is the Showalter Stability Index (8, p. 64). This index is merely the difference between the observed temperature at 500 mb and the temperature a parcel of air would have if lifted adiabatically from 850 mb to 500 mb. Essentially, the Showalter Index is a measure of upper atmospheric stability.

As figure 7 illustrates, the correlation of this stability index with suspended particulate is - 0.170, indicating that upper atmospheric stability is a poor predictor of pollution concentrations.

## Morning Suspended Particulate as a Function of the Modified Showalter Stability Index

By applying the index discussed in the previous section to the layer of air between the surface and 850 mb, the correlation improved from a value of -0.170 to a value of 0.654. This should leave no doubt that the stability of the layer of air in the first 3500 feet of the atmosphere influences pollution concentrations on a given morning in Medford, Oregon, more than the stability in higher layers (see Figure 8).

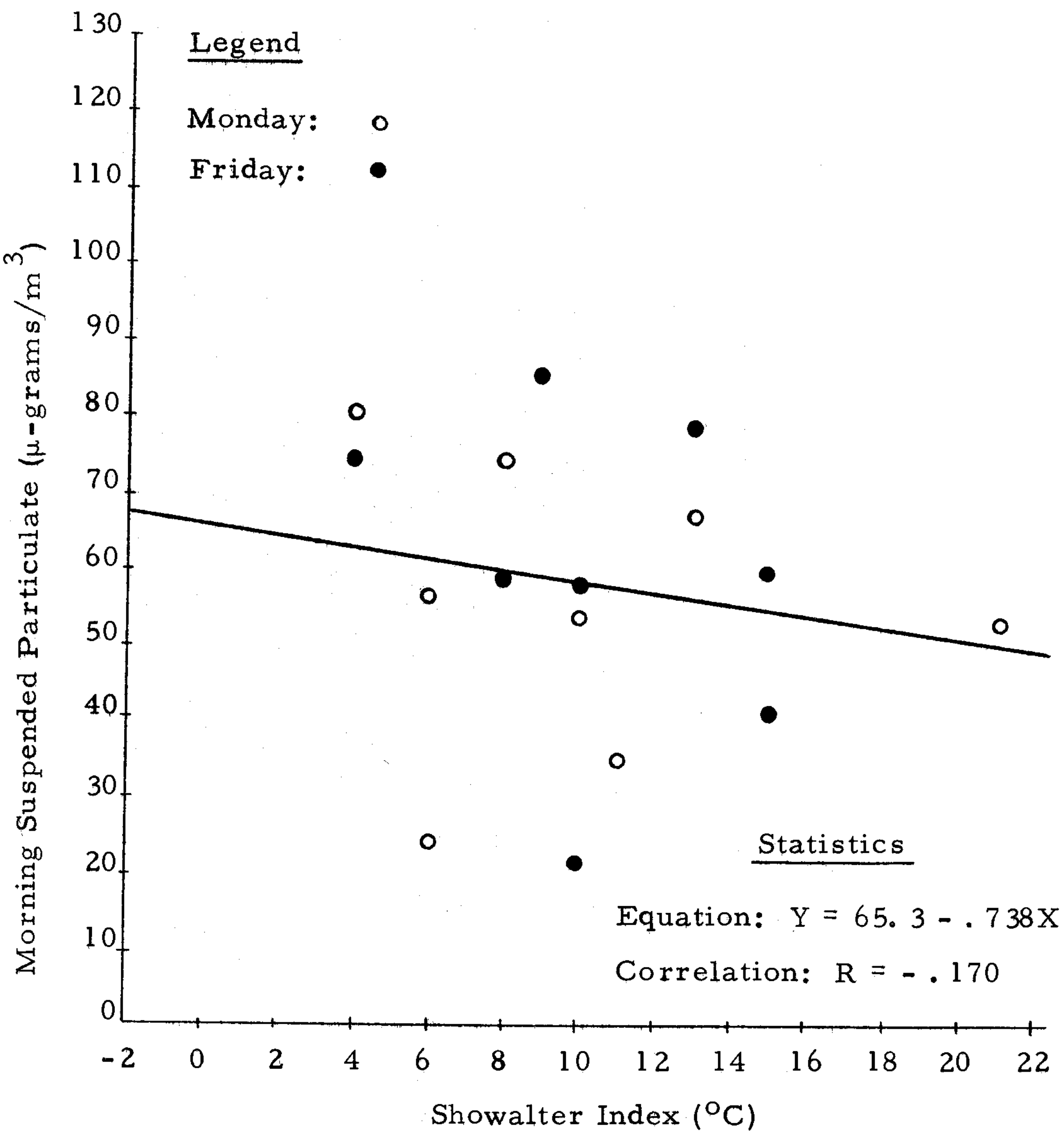



Figure 7. Suspended Particulate as a Function of the Showalter Stability Index (850 mb to 500 mb).

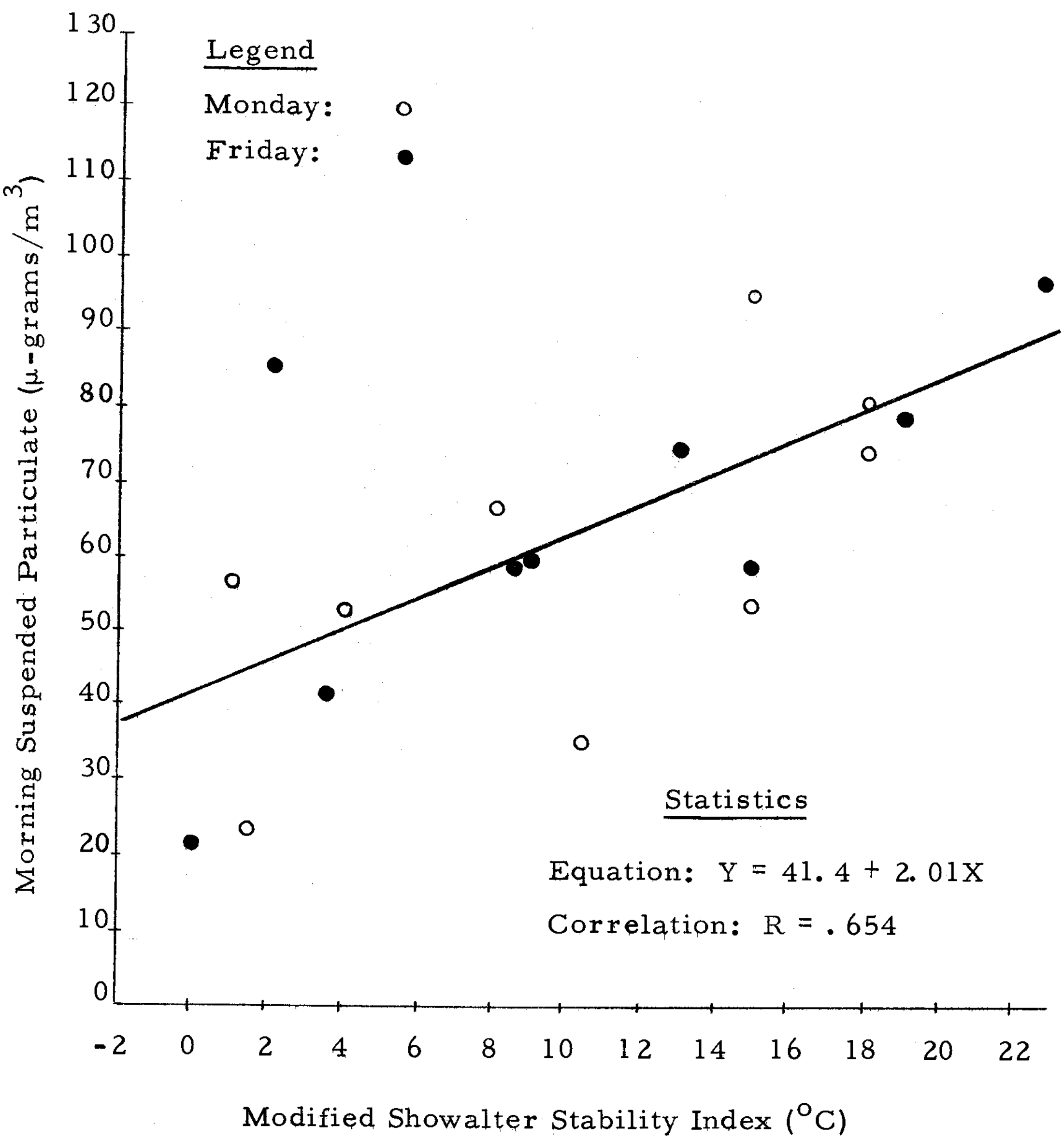



Figure 8. Morning Suspended Particulate as a Function of the Modified Showalter Stability Index (Surface to 850 mb).

Morning Suspended Particulate as a Function of a Persistence Index Based on the Modified Showalter Index

The concept underlying the persistence index is that the pollution measured on a given morning is not only dependent on that morning's stability but also on the stability of previous days. Ramsdell has shown that pollution concentrations are related to such an index (15, p. 19).

By weighting the Modified Showalter Index for the morning of the prediction ($S_{m_0}$) by one and one-half, one for the previous morning ($S_{m_{-1}}$), and one-half for the morning of the day before ($S_{m_{-2}}$), and summing these three values ($P = 3/2\, S_{m_0} + S_{m_{-1}} + 1/2\, S_{m_{-2}}$), a persistence index was obtained which was then correlated with suspended particulate (see Figure 9). The correlation resulted in a value of 0.676 while the correlation of suspended particulate with the unweighted Modified Showalter Index was 0.654. Perhaps by using a different weighting scheme and taking afternoon soundings into consideration, a persistence index having a higher correlation could have been developed.

The Modified Showalter Index was chosen as the basis of a persistence index because the Showalter Index is widely used by the U. S. Weather Bureau (8, p. 64) and can be evaluated even in the absence of an inversion.

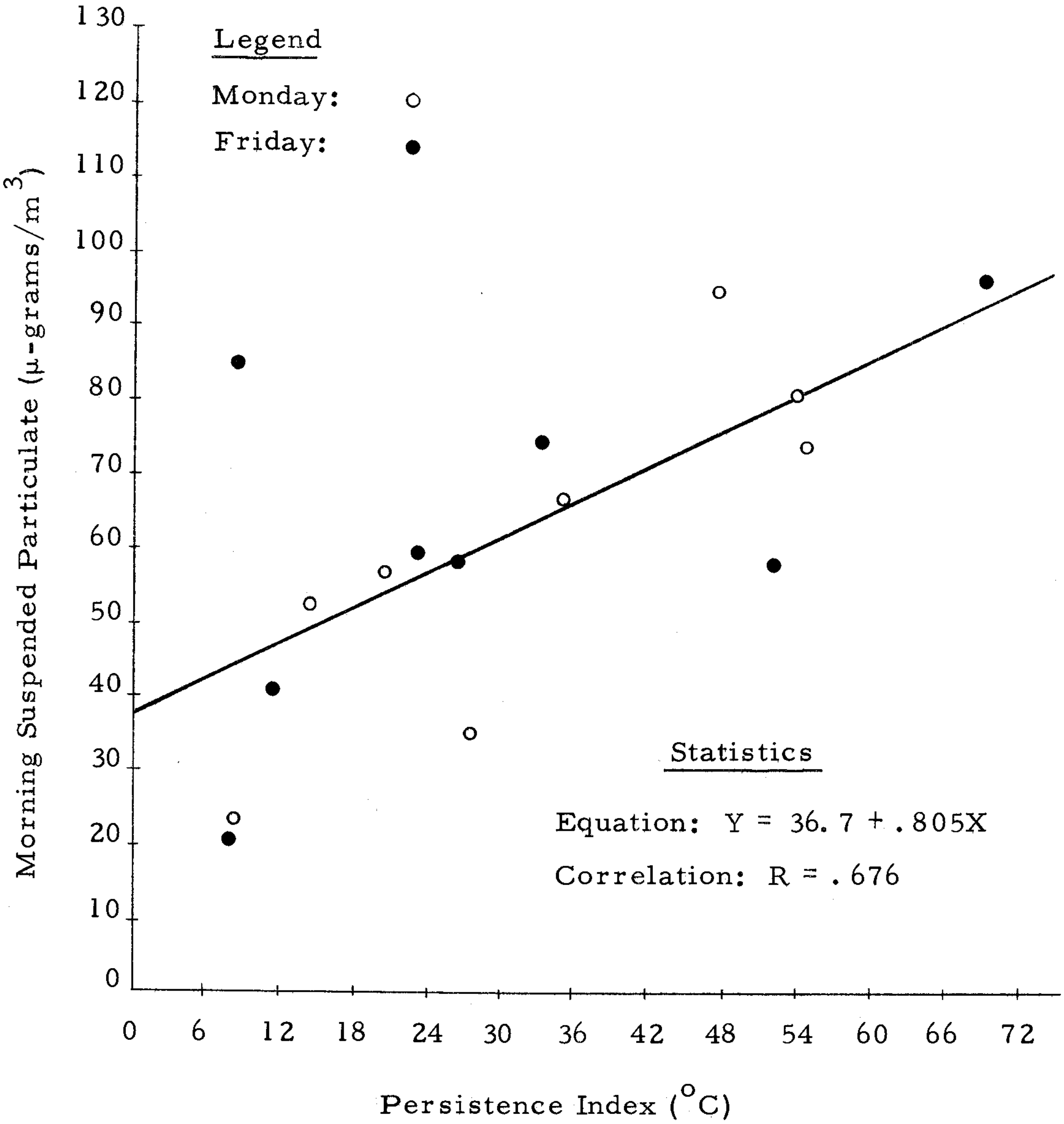



Figure 9. Morning Suspended Particulate as a Function of a Persistence Index Based on the Modified Showalter Index ($P = 3/2\, S_{m_0} + S_{m_{-1}} + 1/2\, S_{m_{-2}}$).

Morning Suspended Particulate as a Function of Inversion Energy

Figure 10 illustrates the correlation between morning concentrations of suspended particulate and inversion energy, defined as the change in kinetic energy in moving a unit mass of air from the surface to the top of the inversion (8, p. 63). Mathematically, a kinetic energy change between any two pressure levels can be expressed as follows:

$$\frac{w_2^2 - w_1^2}{2} = R_d \int_1^2 (T'_v - T_v)\, d(\ln p) = R_d(\overline{T}'_v - \overline{T}_v) \ln \frac{P_1}{P_2}$$

where:

$w_1$ = vertical velocity at lower level,

$w_2$ = vertical velocity at upper level,

$R_d$ = gas constant for dry air (0.287 joule $g^{-1}$ $^oK^{-1}$),

$\overline{T}_v$ = average virtual temperature of the environment,

$\overline{T}'_v$ = average virtual temperature of a parcel lifted from the lower level to the upper level,

$P_1$ = pressure at the lower level, and

$P_2$ = pressure at the upper level (8, p. 63).

Rather than using this equation, the energy was approximated on an area basis from a pseudo-adiabatic diagram (WB Form 770-11, U.S. Department of Commerce). The area proportional to this energy is enclosed by the temperature sounding to the top of the

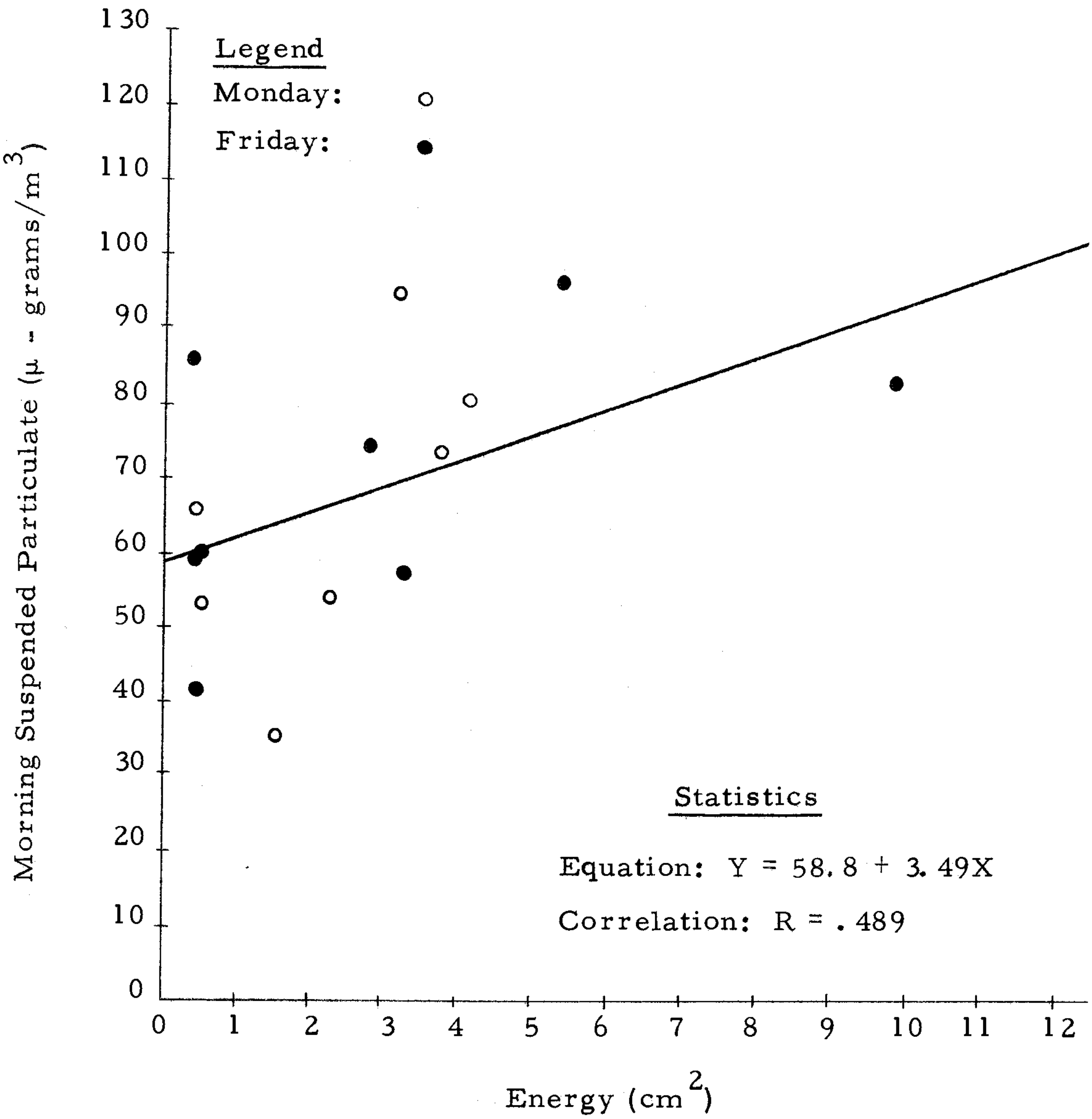



Figure 10. Morning Suspended Particulate as a Function of Inversion Energy.

inversion, the dry adiabat passing through the surface temperature and the isobar at the top of the inversion. In using the dry adiabat for determination of this area, it was thereby assumed that pseudo-adiabatic expansion could be overlooked without incurring serious error.

Since the strength of an inversion is directly proportional to the energy required to lift a unit mass of air from the surface to the top of the inversion, a positive correlation resulted between suspended particulate and inversion energy. A reason for a correlation coefficient of only 0.489 will be given in the next section. In Figures 10 and 11, the units of $cm^2$ on the abscissa refer to the area enclosed on the pseudo-adiabatic diagram.

## Morning Suspended Particulate as a Function of Sounding Energy to 850 mb

As mentioned above, the top of the inversion was arbitrarily chosen as the lowest level in the atmosphere where isothermal or non-inversion conditions were indicated by the sounding. By relating inversion energy to concentrations of suspended particulate, a true measure of the strength of the inversion regime was often not obtained because a substantial depth of atmosphere with near-isothermal conditions was omitted above the inversion. In order to improve this situation, the sounding energy was obtained to a height of 850 mb, and

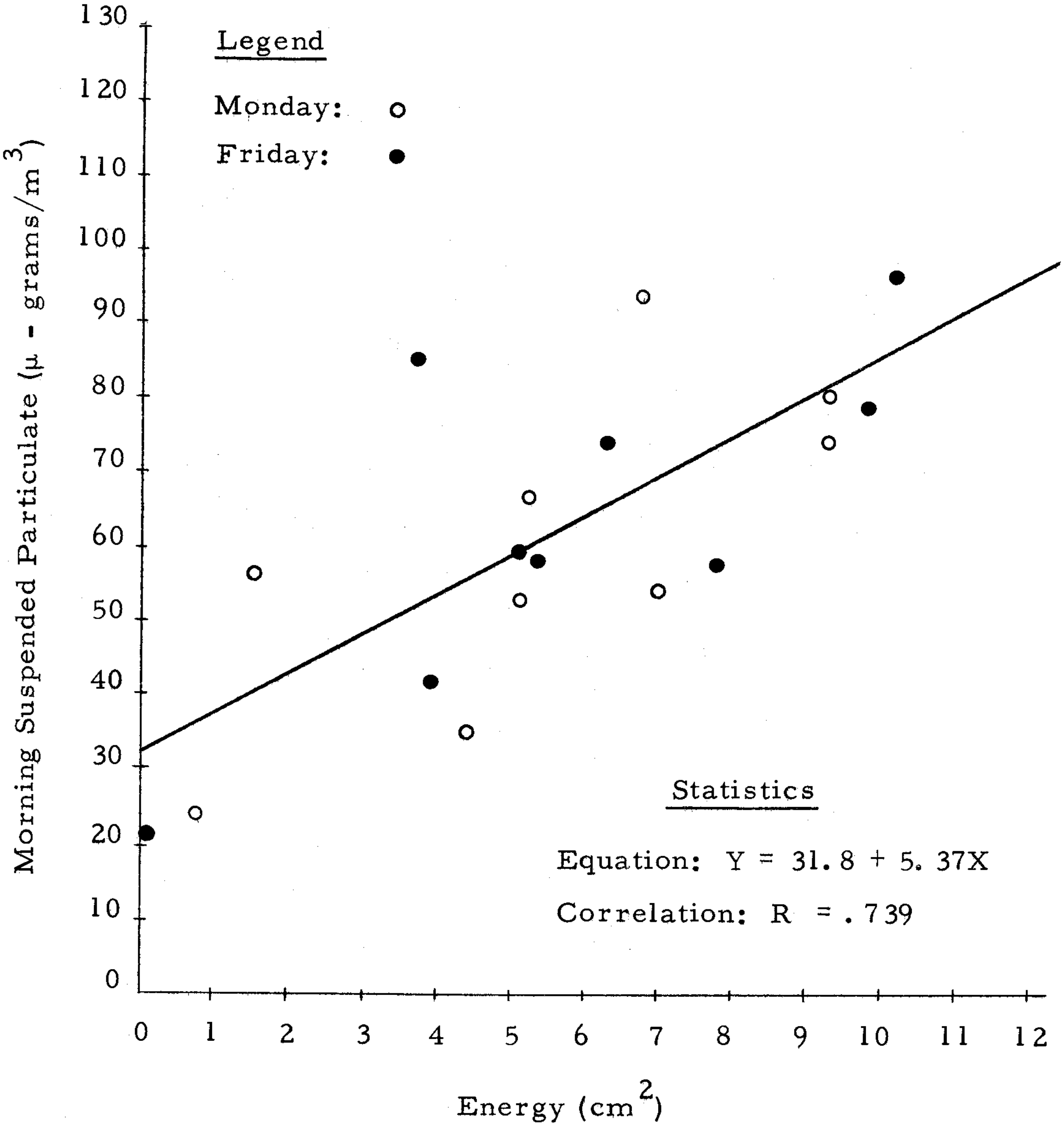



Figure 11. Morning Suspended Particulate as a Function of Sounding Energy to 850 mb.

this measure was related to concentrations, as seen in Figure 11, where a much improved correlation results.

Considering again the acceptability of relationships with R $\geq$0.65 as predictors of morning concentrations of suspended particulate, we see that to this point four measures of stability of the lower atmosphere have been identified as meeting this criterion. The sounding energy to 850 mb, the temperature difference between 850 mb and the surface, and the modified Showalter Index and its use in a persistence index are all acceptable as predictors, and all are applicable whether or not an inversion is present.

Morning Suspended Particulate as a Function of Surface Relative Humidity

In order to determine whether surface humidity is related to concentrations of suspended particulate, an average of the hourly humidity observations taken by the U. S. Weather Bureau between 0600 and 1200 PST was correlated with suspended particulate. This time interval was chosen so as to encompass the peak pollution period of the morning in addition to being a representative sample of morning humidity. As shown in Figure 12, surface relative humidity and suspended particulate are poorly correlated.

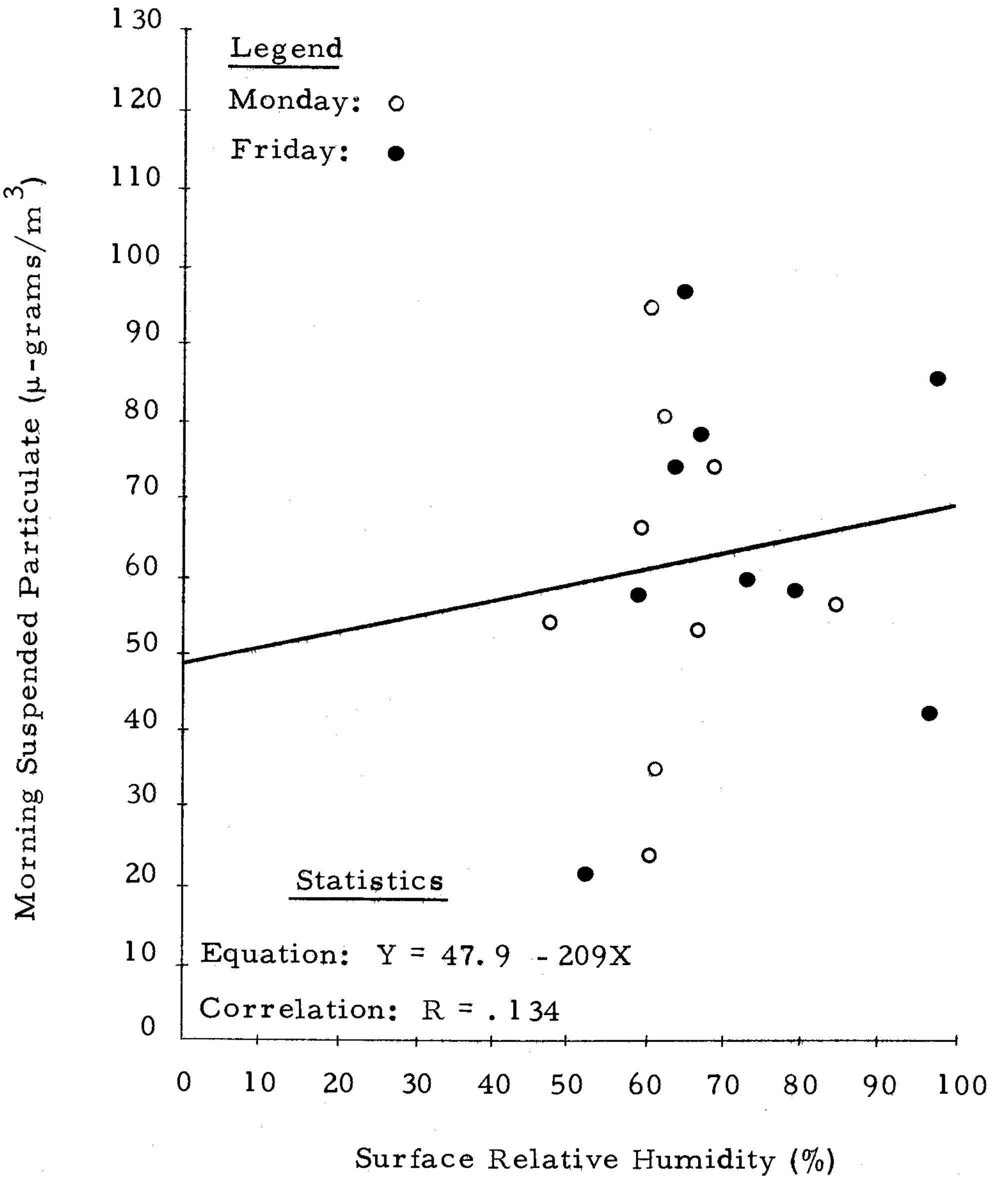



Figure 12. Morning Suspended Particulate as a Function of Surface Relative Humidity.

Morning Suspended Particulate as a Function of Surface Wind Speed

Figure 13 shows a relationship between suspended particulate and wind speed. As in the previous correlation, the wind speed was determined by averaging hourly wind speed observations for the period of 0600 to 1200 PST. In practice, wind speeds of two knots or less are reported as "calm" in climatological data published by the U. S. Weather Bureau (18). Averaging hourly wind speeds in this study, "calms" were taken to mean zero wind speed.

A correlation of -0.555 was obtained between wind speed and suspended particulate. Despite the marginal value of the correlation coefficient, the negative sign indicates that as average wind speed increases, pollution decreases, a result that one would expect, in the absence of substantial veering of the wind (15, p. 2).

Morning Suspended Particulate as a Function of Evening Suspended Particulate

As a matter of interest, Figure 14 is presented to show that a good correlation exists between morning concentrations of suspended particulate and those of the previous evening ($R = 0.833$). This graph illustrates that morning concentrations of particulate are on the average more than 20 $\mu$-grams/$m^3$ higher than evening concentrations, as already shown by Table 1. The close relationship between these

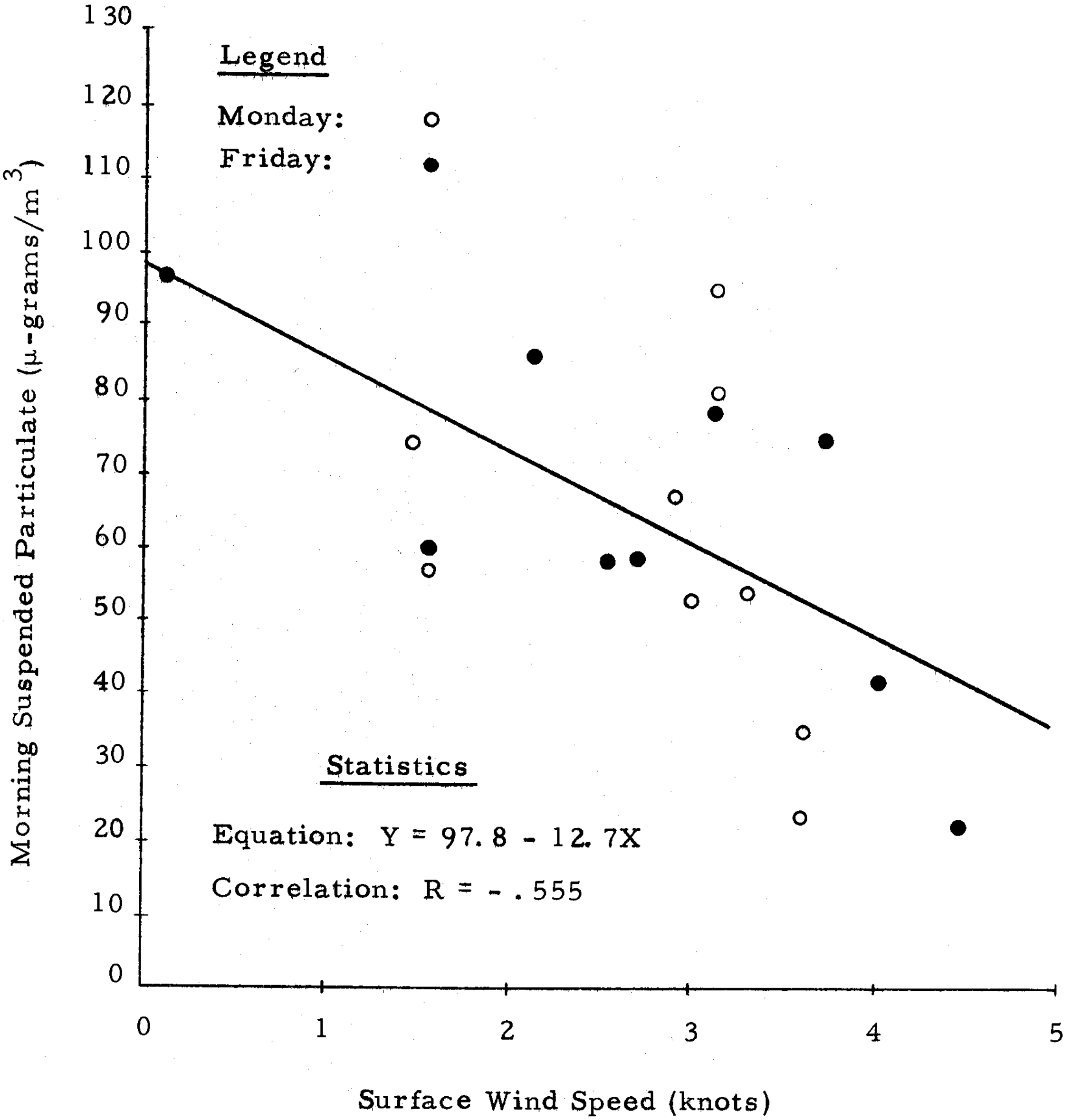



Figure 13. Morning Suspended Particulate as a Function of Surface Wind Speed.

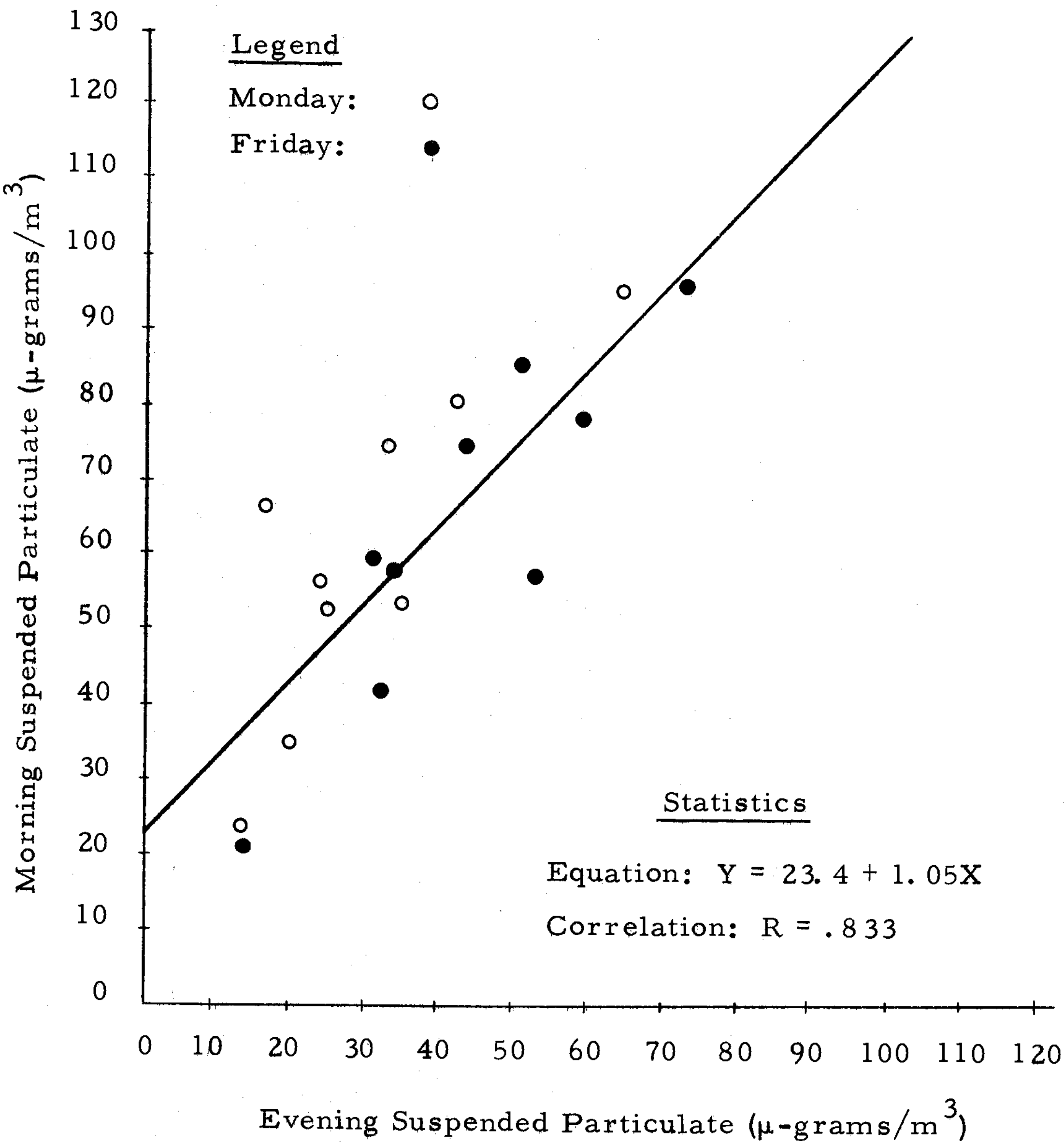



Figure 14. Morning Suspended Particulate as a Function of Evening Suspended Particulate.

two non-meteorological variables might indicate that the radiation inversion has a strong influence on both evening and morning pollution concentrations.

# MULTIVARIATE PREDICTION MODELS

## A Work Week Model Based on Graphical Analysis

Stability, wind speed, wind direction, and precipitation are the meteorological factors usually employed in forecasting pollution concentrations (2, 6, 9). One technique that can be used to combine these variables into a prediction scheme is coaxial graphical correlation (6), the method initially chosen for devising a model.

Before any attempt was made to devise the model, precipitation was eliminated at the outset. The number of mornings having precipitation were few, and when precipitation did occur, the amounts were relatively small (see Appendix, p. 55 ).

On the assumption that accumulation of pollutants may result when radiation inversions recur on consecutive days, the persistence index described above was adopted as the stability parameter. With the Showalter Index underlying this parameter so quickly calculated and so widely accepted, it was chosen here in preference to the energy area relationship having a slightly higher simple correlation with concentrations.

Wind speed was determined by the procedure described above (see page 32). On a diagram of the persistence index versus particulate concentration, wind speed categories were set forth subjectively (Figure 15). No improvement in the graphical correlation model was

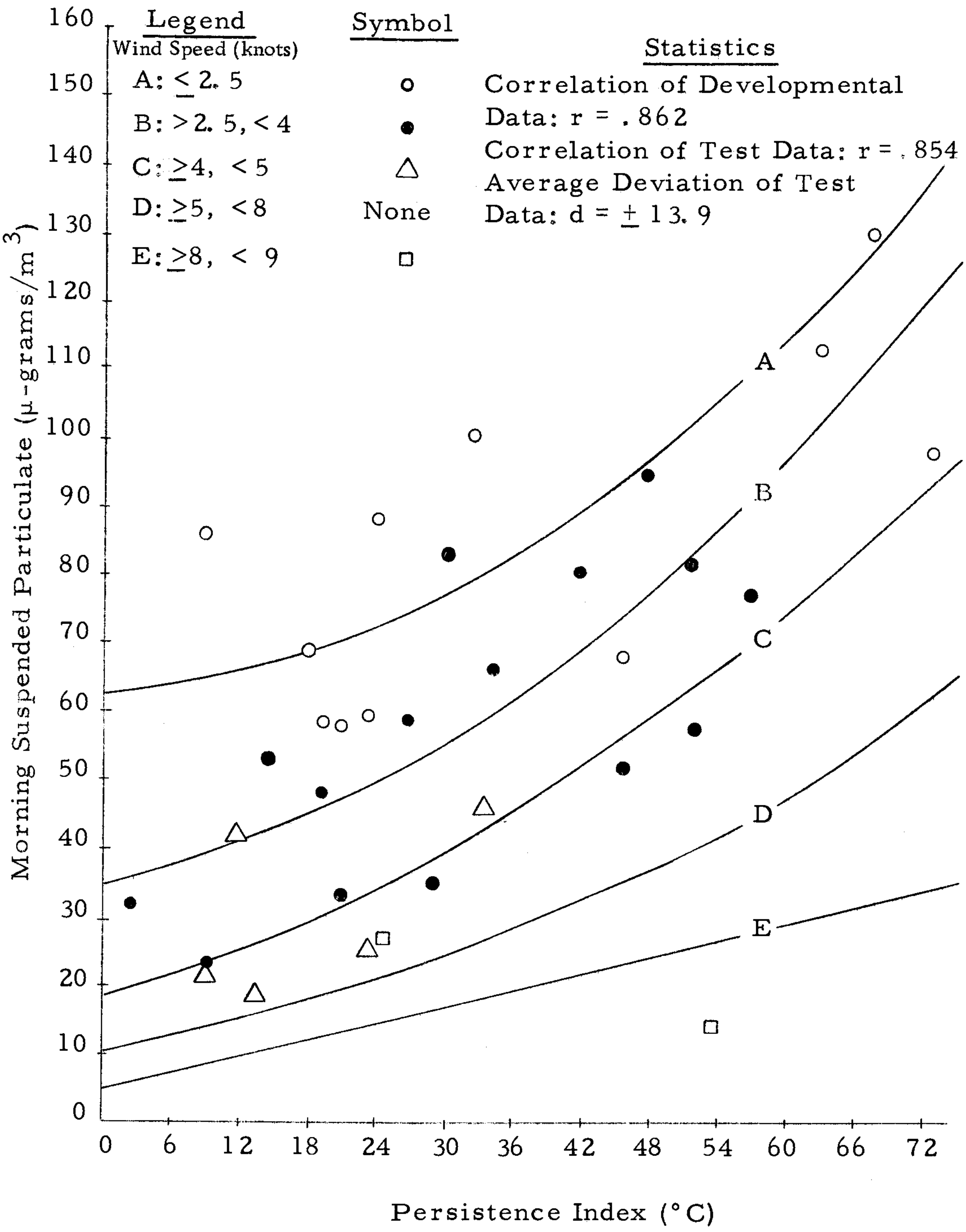



Figure 15. A Work Week Model Based on Graphical Analysis.

apparent when the prevailing wind direction between 0600 and 1200 PST was used as the third predictor in a coaxial scheme (11, p. 316). This lack of relevance may be explained by the fact that during the period of observation dealt with here, direction of the morning winds in Medford was almost exclusively from the northwest quadrant (see Table 2).

Table 2. Frequency of Prevailing Wind Direction at the Medford Municipal Airport for the Sampling Period of August 23, 1964 through October 31, 1964 (Morning Only).

| | C | N | NW | W | SW | S | SE | E | NE |
|---|---|---|---|---|---|---|---|---|---|
| Number of Observations | 19 | 23 | 13 | 7 | 1 | 2 | 1 | 0 | 0 |
| Frequency (%) | 28.8 | 34.8 | 19.7 | 10.6 | 1.5 | 3.1 | 1.5 | 0 | 0 |

It should be noted how sensitive pollution concentrations appear to be to small variations in the morning wind speed.

In summary, while coaxial methods may be useful for graphical prediction procedures in air pollution meteorology, the scheme presented with only two predictors in Figure 15 appears optimal for the climatic and topographical regime found during late summer in Medford.

## Work Week Models Based on Regression Analysis

Table 3 presents prediction equations for estimating concentrations of suspended particulate developed by regression analysis

Table 3. Work Week Models Based on Regression Analysis

| | | | |
|---|---|---|---|
| Experimental Model (Linear) | $Y = a_o + a_1X_1 + a_2X_2$ | | |
| Variables | Y = Suspended Particulate | $X_1$ = Persistence Index | $X_2$ = Wind Speed |
| Prediction Model | $Y = 70.5 + .734X_1 - 10.7X_2$ | | |
| Data | Developmental | Test | |
| Correlation | $\lvert R \rvert = .850$ | $r = .800$ | $d = \pm 19.1$ |
| Experimental Model (Nonlinear) | $Y = a_o + a_1X_1 + a_2X_2 + a_3\frac{1}{X_1} + a_4\frac{1}{X_2} + a_5X_1^2 + a_6X_2^2 + a_7\frac{1}{X_1^2} + a_8\frac{1}{X_2^2} + a_9e^{X_1} + a_{10}e^{X_2} + a_{11}(\ln X_1) + a_{12}(\ln X_2)$ | | |
| Prediction Model | $Y = 76.8 + .527X_1 - 33.5(\ln X_2)$ | | |
| Correlation | $\lvert R \rvert = .842$ | $r = .821$ | $d = \pm 23.1$ |

for use with information on atmospheric stability and wind speed(16). In the table, the equations tested are labeled Experimental Models. The results of the analysis are titled Prediction Models.

In this regression analysis, the independent variable which correlates best with the dependent variable becomes the first term of the regression equation. The position of the remaining terms is determined on the basis of how well they decrease the residual (10, 12). In order for a prediction model to be accepted as valid, each term must produce a significantly high value in a F-test with 1 and (N-1-i) degrees of freedom. The five percent level of significance is used, N is the number of observations, i the position of the predictor, and the value of F is:

$$\frac{(\text{Regression Sum of Squares})_{(i-1)} - (\text{Regression Sum of Squares})_i}{(\text{Total Sum of Squares}) - (\text{Regression Sum of Squares})_i}$$

In addition, the equation as a whole must produce a value of F with i and (N-1-i) degrees of freedom significantly large at the five percent level, with i here being the number of predictors.

A point of interest is that, while both linear and non-linear models may be expected to account for about the same amount of variability in concentrations ( $|R|$ between about .80 and .85), the non-linear scheme suggests wind speed is logarithmically related rather than linearly related. All three prediction models presented in this chapter appear to provide a better basis for prediction of morning concentrations of particulate than any of the models employing only one predictor considered in the previous chapter. This advantage may accrue, however, only if a scheme becomes available for accurate forecasting of low wind speeds during the morning hours.

# MORNING SUSPENDED PARTICULATE AS A FUNCTION OF VISIBILITY

Figure 16 shows a relationship between pollution and visibility. The visibility was determined by averaging the hourly observations taken by U. S. Weather Bureau personnel at 0700 through 1000 PST. According to tape sample analysis, this is probably the worst pollution period of the day (3, p. 28).

In order to minimize the influence of outside factors, the analysis of the effect of suspended particulate on visibility was confined to those mornings when no clouds were present (see Appendix, page 54). An attempt was made to distinguish the effects of moisture and sun angle on visibility by use of symbols presenting information on mean morning surface humidity and month of the year. Subjective judgement of Figure 16 suggests these two additional variables are not relevant. As mentioned earlier, a relationship such as the one in Figure 16 could provide the basis for specifying concentrations associated with minimally acceptable visibility. Using short-term, meteorologically based prediction schemes presented above, the potential for exceeding the critical values of concentration could be identified in time for auxiliary gas-firing in waste burners to be employed as a means of maintaining acceptable visibility in the Medford area.

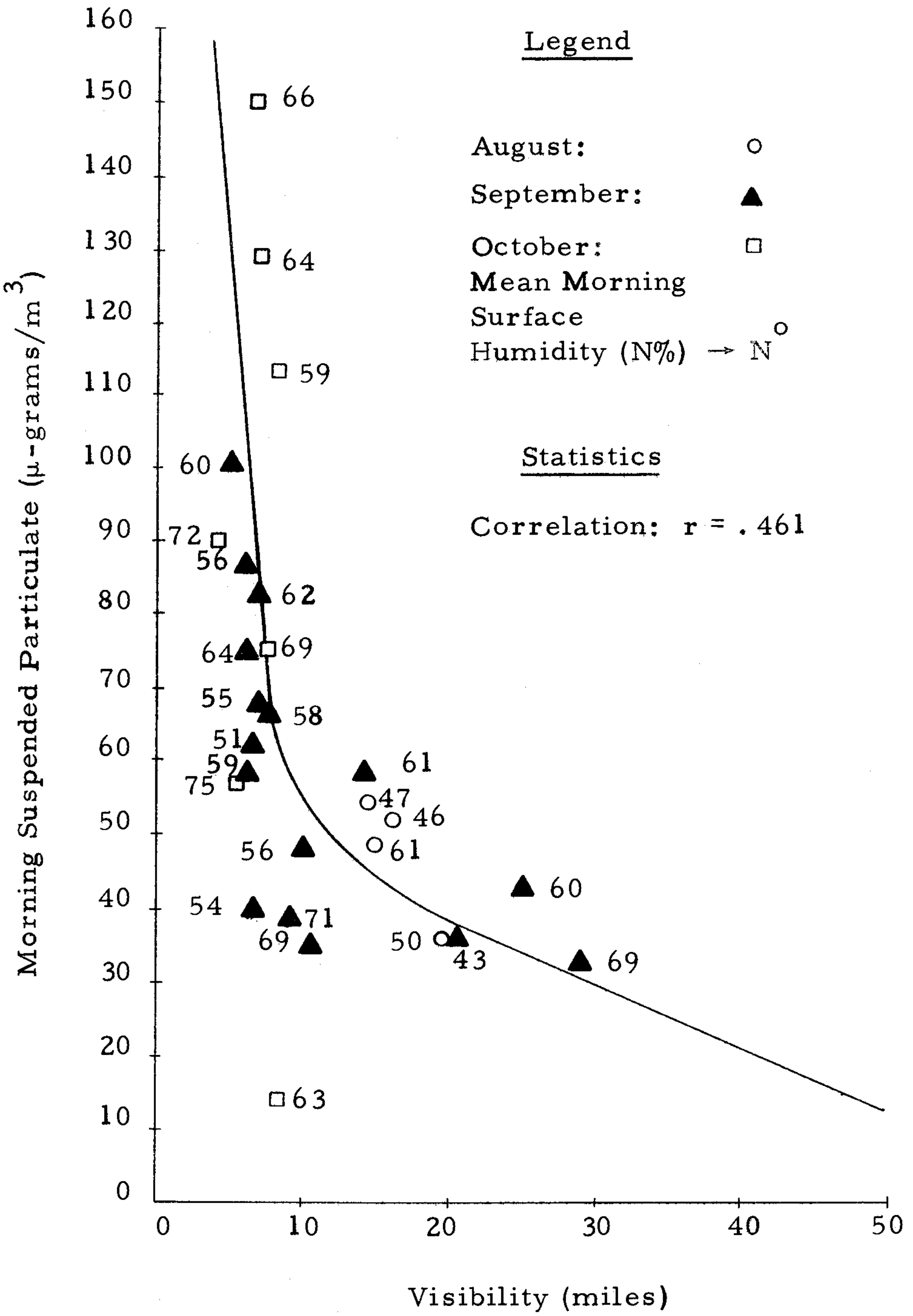



Figure 16. Morning Suspended Particulate as a Function of Visibility (No Sky Cover Cases Only).

# CONCLUSIONS

Based on the results of this study, the following conclusions appear tenable.

1. Four closely related measures of the stability of the lower atmosphere over Medford each provide a suitable basis for predicting the mean concentrations of suspended particulate at the Medford Airport during the hours 0300 to 1100 PST of the late summer months. All four measures would be available daily at about 0400 PST, and in the order of decreasing suitability they are:

   a. the sounding energy between the surface and 850 mb (R =0.739),

   b. the temperature difference between 850 mb and the surface (R =0.686),

   c. the persistence index based on the Modified Showalter Stability Index (R =0.676), and

   d. the Modified Showalter Index itself (R =0.654).

2. While a forecast of mean morning wind speed by itself is unsuitable as a basis for prediction, this variable employed in a multivariate prediction model with the persistence index appears to offer a potentially more accurate method of predicting morning concentrations of suspended particulate at the Medford Airport as compared with any of the methods in (1) above.

3. Visibility during the morning hours at Medford is sufficiently well related to concentrations of particulate during the same period to enable translating visibility criteria into concentration criteria for maximum allowable pollution levels. This translation, together with use of the prediction models developed in this study, should enable maintenance of visibility acceptable to the summer tourist industry in the Medford area.

## RECOMMENDATIONS

Two types of recommendation are appropriate at the conclusion of this thesis. First, analyses in extension of those presented here should be undertaken to clarify some of the points raised. In particular,

1. Methods should be developed to permit accurate forecasts of low wind speeds in the morning hours at Medford. The multivariate scheme developed in this thesis shows concentration of pollutants is extremely sensitive to this variable, and good forecasts of it would enable significant improvement in forecasts of pollution.

2. Exploration should be undertaken of the matter of whether or not pollutants accumulate during a sequence of days having recurring morning inversions. By employing information on atmospheric stability from the 1530 PST radiosonde flight at Medford in addition to the information from the early morning employed here, but considering the various stability parameters and other weighting patterns in calculation of a persistence index, the question could be explored rather thoroughly.

3. Recommendations of the second type would be to extend the methods developed in this thesis so as to consider the field data gathered in November and December of 1964. Meteorological factors,

most notably cloud cover (i. e. heating rate) and wind direction, would exhibit greater variability, and perhaps differing orders of importance, during these winter months. In such an extension, coaxial methods might well play a key role.

# BIBLIOGRAPHY

1. Allen, Eric W., Jr. Editor, Medford Mail Tribune, Personal communication. Medford, Oregon. May, 1965.

2. Baynton, H. W. Multiple correlations of particulate air pollution with weather factors at Detroit and Windsor. Bulletin of the American Meteorological Society 37:333-337. 1956.

3. Boubel, R. W., G. E. Thornburgh, and B. R. Pavelka. A study of wood waste disposal by combustion and its effect on air quality in the Medford area. Corvallis, 1965. 60 numb. leaves. (Oregon State University. Engineering Experiment Station. EES Project 307).

4. Boubel, Richard W. Correlation of emission data with air quality data for a valley area. Paper delivered at the 26th Annual Conference of the American Industrial Hygiene Association, Houston, Texas, 1965.

5. Corder, Stanley E. Assistant Professor of Mechanical Engineering, Oregon State University. Personal communication. Corvallis, Oregon. May, 1965.

6. Dickson, R. R. Meteorological factors affecting particulate air pollution of a city. Bulletin of the American Meteorological Society 42:556-560. 1961.

7. Ezekiel, Mordecai. Methods of correlation analysis. 2nd ed. New York, Wiley, 1941. 531 p.

8. Haltiner, George J., and Frank L. Martin. Dynamical and physical meteorology. New York, McGraw-Hill, 1957. 470 p.

9. Holzworth, George C. Estimates of mean maximum mixing depths in the contiguous United States. Monthly Weather Review 92:235-242. 1964.

10. Janssen, Larry. Supervisor of the Statistics Computer Laboratory, Oregon State University. Personal communication. Corvallis, Oregon. May, 1965.

11. Linsley, Ray K., Jr., Max A. Kohler, and Joseph L. H. Paulhus. Hydrology for engineers. New York, McGraw-Hill, 1958. 340 p.

12. Maki, William. Graduate Assistant in Statistics, Oregon State University. Personal communication. Corvallis, Oregon. May, 1965.

13. Markee, E. H., Jr. Relationships of an air quality measurement to meteorological parameters. Journal of the American Industrial Hygiene Association 20:50-55. February, 1959.

14. Oregon. State Sanitary Authority. The air pollution problem in Medford, Oregon. Portland, 1960. 57 numb. leaves.

15. Ramsdell, James Vanner, Jr. A study of air pollution potentiality in the Willamette Valley. Master's thesis. Corvallis, Oregon State University, 1962. 117 numb. leaves.

16. Regression Analysis Program, Computer Program Library for the IBM 1410, Oregon State University, Corvallis, Oregon.

17. Robinson, Elmer. Some air pollution aspects of the Los Angeles temperature inversion. Bulletin of the American Meteorological Society 33:247-250. 1952.

18. U. S. Weather Bureau. Local climatological data, (supplement). Washington, 1964. Medford, Oregon.

19. Williams, Philip, Jr. Air pollution potential over the Salt Lake Valley of Utah as related to stability and wind speed. Journal of Applied Meteorology 3:92-97. 1964.

20. World Health Organization. Air pollution. New York, Columbia University Press, 1961. 442 p.

APPENDICES

# LEGEND OF SYMBOLS

| Variable | Symbol |
|---|---|
| Concentration ($\mu$-grams/$m^3$) for the eight-hour period beginning 0330 on day indicated | $C_1$ |
| Concentration ($\mu$-grams/$m^3$) for the eight-hour period beginning 1130 on day indicated | $C_2$ |
| Concentration ($\mu$-grams/$m^3$) for the eight-hour period beginning 1930 on day indicated | $C_3$ |
| Temperature thickness of the inversion (°C) | A |
| Temperature difference index (°C) | B |
| Morning temperature range (°F) | D |
| $T_{max}$ (°F), 0700-1100 PST | E |
| $T_{min}$ (°F), 0700-1100 PST | F |
| Maximum mixing depth (km) | G |
| Modified Stanford Index (°$C^2$/km) | H |
| $\Delta\theta$ of the inversion (°C) | I |
| $\Delta Z$ of the inversion (km) | J |
| Showalter Index (°C) | K |
| Modified Showalter Index (°C) | L |
| Persistence index (°C) | M |
| Inversion energy ($cm^2$) | N |
| Energy to 850 mb ($cm^2$) | O |
| Relative humidity (%), 0600-1200, PST | P |

| Variable | Symbol |
| --- | --- |
| Wind speed (knots), 0600-1200 PST | Q |
| Wind direction, 0600-1200 PST | R |
| Visibility (miles), 0700-1000 PST | S |
| Sky cover, 0700-1100 PST | T |
| Subsidence inversion | U |
| Precipitation (inches), 0350-1550 PST | V |
| Test data | W |

# TABULATION OF DATA

| No. of Observation | Date | Day of Week | $C_1$ | $C_2$ | $C_3$ | A | B | D |
|---|---|---|---|---|---|---|---|---|
| 1 | Aug | Sun | 35.8 | 24.2 | 43.2 | 8.3 | + 6.8 | 22 |
| 2 | 24 | Mon | 53.6 | 36.4 | 35.0 | 5.8 | + 4.6 | 21 |
| 3 | 25 | Tues | 52.0 | 48.8 | 47.6 | 6.6 | + 3.9 | 23 |
| 4 | 26 | Wed | 27.6 | 18.0 | 20.9 | None | - 9.3 | 8 |
| 5 | 27 | Thurs | 48. | 25. | 22.5 | 1.6 | - 0.1 | 13 |
| 6 | 28 | Fri | 21.6 | 19.1 | 12.7 | None | -10.0 | 6 |
| 7 | 29 | Sat | 25.1 | 16.3 | 17.5 | 2.3 | + 0.4 | 17 |
| 8 | 30 | Sun | 18.6 | 19.7 | 26.4 | None | - 7.0 | 4 |
| 9 | 31 | Mon | 23.8 | 47.4 | 13.4 | None | - 7.1 | 9 |
| 10 | Sept | Tues | 32.4 | 27.1 | 22.3 | 0.1 | - 6.2 | 9 |
| 11 | 2 | Wed | 35.9 | 20.5 | 26.9 | 2.0 | - 1.3 | 14 |
| 12 | 3 | Thurs | 33.4 | 35.1 | 29.0 | 4.5 | + 3.5 | 19 |
| 13 | 4 | Fri | 75.0 | 38.6 | 43.1 | 5.9 | + 5.3 | 21 |
| 14 | 5 | Sat | 38.7 | 31.7 | 51.0 | 3.9 | - 0.2 | 19 |
| 15 | 6 | Sun | 34.7 | 28.6 | 34.7 | 3.5 | + 1.7 | 17 |
| 16 | 7 | Mon | 35. | Miss | 20.0 | 4.1 | + 3.4 | 21 |
| 17 | 8 | Tues | Miss | 22.4 | Miss | None | - 8.5 | 8 |
| 18 | 9 | Wed | 58.6 | 41.4 | 47.6 | 3.8 | + 2.1 | 18 |
| 19 | 10 | Thur | 101.0 | 49.8 | 46.3 | 8.0 | + 7.7 | 21 |
| 20 | 11 | Fri | 87.6 | 44.6 | 41.4 | 7.5 | + 5.6 | 23 |
| 21 | 12 | Sat | 62.5 | 20.9 | 43.8 | 8.2 | + 6.9 | 22 |
| 22 | 13 | Sun | 40.3 | 48.7 | 44.1 | 8.4 | + 6.6 | 20 |
| 23 | 14 | Mon | 66.7 | 28.7 | 16.6 | 4.4 | + 0.1 | 20 |
| 24 | 15 | Tues | 83.1 | 45.2 | 39.6 | 4.3 | + 2.2 | 19 |
| 25 | 16 | Wed | 68.1 | 64.0 | 40.5 | 11.9 | +11.9 | 24 |
| 26 | 17 | Thurs | 25.6 | 18.4 | 17.0 | None | - 6.9 | 3 |
| 27 | 18 | Fri | 59.5 | 42.2 | 31.3 | 4.1 | + 1.8 | 18 |
| 28 | 19 | Sat | 47.7 | 31.3 | 46.5 | 6.3 | + 5.8 | 24 |

| No. of Observation | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|
| 1 | 84 | 62 | 2. 1 | 100. 0 | 15 | 2. 1 | + 6 | +16. 0 |
| 2 | 81 | 60 | 2. 0 | 78. 0 | 13 | 2. 0 | +10 | +15. 0 |
| 3 | 83 | 60 | 2. 0 | 84. 5 | 13 | 2. 0 | + 8 | +14. 0 |
| 4 | 70 | 62 | None | None | None | None | +12 | + 2. 0 |
| 5 | 69 | 50 | 4. 0 | 18. 0 | 3 | 0. 5 | +12 | + 7. 0 |
| 6 | 62 | 56 | None | None | None | None | +10 | 0. 0 |
| 7 | 65 | 48 | 3. 6 | 31. 3 | 5 | 0. 8 | +13 | + 8. 0 |
| 8 | 63 | 59 | None | None | None | None | +10 | + 2. 0 |
| 9 | 60 | 51 | None | None | None | None | + 6 | + 1. 5 |
| 10 | 59 | 50 | 4. 2 | 2. 5 | 1 | 0. 4 | + 3 | 0. 0 |
| 11 | 61 | 47 | 3. 1 | 23. 0 | 4 | 0. 7 | +10 | + 5. 5 |
| 12 | 64 | 45 | 2. 3 | 15. 0 | 6 | 2. 4 | + 8 | +11. 0 |
| 13 | 69 | 48 | 2. 3 | 22. 2 | 7 | 2. 2 | + 4 | +13. 0 |
| 14 | 68 | 49 | 3. 0 | 60. 0 | 6 | 0. 6 | + 4 | + 8. 0 |
| 15 | 65 | 48 | 2. 5 | 62. 5 | 5 | 0. 4 | + 8 | + 8. 0 |
| 16 | 66 | 45 | 2. 5 | 42. 6 | 9 | 1. 9 | +11 | +10. 5 |
| 17 | 62 | 54 | None | None | None | None | +14 | 0. 0 |
| 18 | 62 | 44 | 3. 2 | 11. 4 | 5 | 2. 2 | +13 | + 9. 5 |
| 19 | 68 | 47 | 2. 0 | 27. 8 | 8 | 2. 3 | + 8 | +16. 0 |
| 20 | 71 | 48 | 1. 9 | 27. 8 | 8 | 2. 3 | +10 | +14. 0 |
| 21 | 72 | 50 | 2. 1 | 36. 9 | 9 | 2. 2 | + 8 | +15. 5 |
| 22 | 73 | 53 | 2. 1 | 7. 6 | 16 | 2. 1 | + 6 | +15. 0 |
| 23 | 67 | 47 | 3. 4 | 51. 5 | 6 | 0. 7 | +13 | + 8. 0 |
| 24 | 65 | 46 | 2. 0 | 70. 0 | 7 | 0. 7 | +12 | +10. 0 |
| 25 | 72 | 48 | 1. 7 | 147. 0 | 23 | 3. 6 | + 7 | +21. 0 |
| 26 | 58 | 55 | None | None | None | None | + 4 | - 1. 0 |
| 27 | 59 | 41 | 3. 6 | 45. 0 | 6 | 0. 8 | +15 | + 9. 0 |
| 28 | 68 | 44 | 2. 0 | 73. 6 | 13 | 2. 3 | +12 | +15. 0 |

| No. of Observation | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|
| 1 | Miss | 2.9 | 7.7 | 49.9 | 1.4 | C | 20.0 | No |
| 2 | Miss | 2.3 | 7.0 | 46.6 | 3.3 | W | 14.5 | No |
| 3 | 44.0 | 2.8 | 7.9 | 46.4 | 3.9 | N | 16.3 | No |
| 4 | 24.5 | None | 0.7 | 52.0 | 8.4 | N | 30.0 | Yes |
| 5 | 19.5 | 0.1 | 4.0 | 61.3 | 2.6 | N | 15.0 | No |
| 6 | 8.0 | None | 0.0 | 52.0 | 4.4 | NW | 22.5 | Yes |
| 7 | 15.5 | 0.4 | 4.6 | 61.6 | 3.9 | N | 22.5 | Yes |
| 8 | 11.0 | None | 1.1 | 59.3 | 7.1 | NW | 25.0 | Yes |
| 9 | 8.3 | None | 0.8 | 60.1 | 3.6 | N | 22.5 | Yes |
| 10 | 2.5 | 0.1 | 1.5 | 86.7 | 3.4 | NW | 5.8 | Yes |
| 11 | 9.0 | 0.3 | 3.9 | 79.6 | 3.7 | N | 7.5 | Yes |
| 12 | 22.0 | 2.7 | 5.0 | 69.0 | 3.1 | NW | 13.8 | Yes |
| 13 | 33.3 | 2.8 | 6.3 | 63.9 | 3.7 | SW | 6.8 | No |
| 14 | 30.5 | 0.4 | 4.4 | 70.9 | 2.1 | W | 8.8 | No |
| 15 | 26.5 | 0.1 | 4.4 | 68.6 | 3.0 | N | 10.3 | Yes |
| 16 | 27.8 | 1.5 | 4.4 | 62.0 | 3.6 | NW | 26.3 | Yes |
| 17 | 14.5 | None | 0.0 | 57.4 | 3.6 | N | 27.5 | Yes |
| 18 | 19.5 | 2.3 | 2.6 | 61.3 | 2.0 | W | 14.8 | No |
| 19 | 33.5 | 3.4 | 7.9 | 59.7 | 1.7 | C | 5.0 | No |
| 20 | 41.8 | 2.9 | 7.7 | 56.4 | 3.1 | NW | 6.0 | No |
| 21 | 45.2 | 3.8 | 8.1 | 51.4 | 3.1 | N | 6.5 | No |
| 22 | 45.0 | 3.5 | 8.1 | 53.6 | 2.3 | NW | 7.3 | No |
| 23 | 34.8 | 0.4 | 5.2 | 57.6 | 2.9 | N | 7.5 | No |
| 24 | 30.5 | 0.3 | 5.1 | 61.9 | 2.7 | N | 7.3 | No |
| 25 | 45.5 | 9.2 | 9.2 | 54.9 | 2.1 | W | 7.3 | No |
| 26 | 24.5 | None | 0.9 | 84.4 | 4.6 | N | 11.3 | Yes |
| 27 | 23.0 | 0.5 | 5.0 | 72.7 | 1.6 | C | 8.3 | Yes |
| 28 | 31.0 | 2.8 | 6.5 | 56.3 | 3.6 | N | 10.0 | No |

| No. of Observation | U | V | W |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | SI | | |
| 7 | | | |
| 8 | | | |
| 9 | | .08 | |
| 10 | | .08 | |
| 11 | | | X |
| 12 | | | |
| 13 | | | X |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | SI | | |
| 18 | | | |
| 19 | | | |
| 20 | | | X |
| 21 | | | |
| 22 | | | |
| 23 | | | |
| 24 | | | |
| 25 | | | |
| 26 | | .01 | |
| 27 | | | |
| 28 | | | |

| No. of Observation | Date | Day of Week | $C_1$ | $C_2$ | $C_3$ | A | B | D |
|---|---|---|---|---|---|---|---|---|
| 29 | 20 | Sun | 16.7 | 23.1 | 16.8 | 0.0 | - 9.1 | 9 |
| 30 | 21 | Mon | 53.0 | 40.4 | 25.4 | 4.4 | + 0.5 | 20 |
| 31 | 22 | Tues | 74.7 | 37.1 | 61.1 | 6.5 | + 6.5 | 21 |
| 32 | 23 | Wed | 81.3 | 41.3 | 58.7 | 7.2 | + 7.2 | 24 |
| 33 | 24 | Thurs | 12.1 | 55.9 | 51.3 | 14.8 | +11.7 | 28 |
| 34 | 25 | Fri | 58. | 18.1 | 53.0 | 8.8 | + 7.2 | 22 |
| 35 | 26 | Sat | Miss | Miss | 62.5 | 6.1 | + 5.7 | 23 |
| 36 | 29 | Tues | 87.2 | 45.4 | 62.5 | Miss | Miss | 23 |
| 37 | 30 | Wed | 74.2 | 42.9 | 48.7 | Miss | Miss | 18 |
| 38 | Oct | Thurs | 36.0 | 36.0 | 16.0 | 1.2 | - 5.9 | 17 |
| 39 | 2 | Fri | 78.9 | 52.0 | 58.9 | 10.6 | +10.6 | 24 |
| 40 | 3 | Sat | 32.8 | 11.9 | 35.8 | 6.5 | + 6.5 | 22 |
| 41 | 4 | Sun | 38.1 | 56.6 | 52.3 | 11.4 | +11.4 | 26 |
| 42 | 5 | Mon | 80.8 | 61.2 | 42.2 | 11.4 | + 9.6 | 21 |
| 43 | 6 | Tues | 77.5 | 76.5 | 41.9 | 11.0 | +10.0 | 25 |
| 44 | 7 | Wed | 14.4 | 26.0 | 61.2 | 11.2 | + 9.0 | 20 |
| 45 | 8 | Thurs | 45.5 | 30.8 | 37.9 | 3.3 | - 1.4 | 10 |
| 46 | 9 | Fri | 59.3 | 25.7 | 33.3 | 4.7 | + 2.2 | 17 |
| 47 | 10 | Sat | 42.9 | 53.1 | 36.3 | 6.2 | + 6.2 | 18 |
| 48 | 11 | Sun | 38.0 | 42.7 | 43.6 | 13.6 | +13.6 | 26 |
| 49 | 12 | Mon | 74.7 | 54.6 | 33.0 | 13.6 | +10.3 | 26 |
| 50 | 14 | Wed | 88.8 | 35.4 | 50.9 | 3.6 | 0.0 | 11 |
| 51 | 15 | Thurs | 18.7 | 19.9 | 20.7 | 1.5 | - 4.8 | 1 |
| 52 | 16 | Fri | 42.1 | 55.3 | 32.2 | 1.8 | - 3.4 | 4 |
| 53 | 17 | Sat | 82.4 | 60.2 | 43.4 | 4.0 | + 2.6 | 17 |
| 54 | 18 | Sun | 57. | 53.0 | 34. | 11.2 | +11.2 | 24 |
| 55 | 19 | Mon | 94.9 | 92.5 | 64.1 | 8. | + 5.0 | 33 |
| 56 | 20 | Tues | 113.4 | 144.8 | 63.4 | 16.4 | +16.4 | 26 |
| 57 | 21 | Wed | 129.4 | 121.5 | 75.4 | 16.6 | +16.6 | 25 |
| 58 | 22 | Thurs | 151.0 | 135.1 | 77.9 | 15.5 | +15.5 | 28 |
| 59 | 23 | Fri | 97.3 | 151.0 | 70.6 | 14.3 | +14.3 | 26 |

| No. of Observations | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|
| 29 | 61 | 52 | 0.6 | 5.7 | 2 | 0.7 | +10 | + 1.0 |
| 30 | 59 | 39 | 3.2 | 45.0 | 6 | 0.8 | +21 | + 4.0 |
| 31 | 66 | 45 | 2.0 | 79.0 | 18 | 4.1 | +11 | +16.0 |
| 32 | 73 | 49 | 1.8 | 26.6 | 8 | 2.4 | +12 | +15.0 |
| 33 | 77 | 49 | 1.4 | 210.0 | 22 | 2.3 | +12 | +21.0 |
| 34 | 71 | 49 | 1.4 | 107.0 | 15 | 2.1 | +10 | +15.0 |
| 35 | 62 | 39 | 2.1 | 128.0 | 8 | 0.5 | +15 | +13.5 |
| 36 | 65 | 42 | Miss | Miss | Miss | Miss | Miss | Miss |
| 37 | 62 | 44 | Miss | Miss | Miss | Miss | Miss | Miss |
| 38 | 61 | 44 | 4.5 | 22.9 | 4 | 0.7 | +20 | + 4.0 |
| 39 | 63 | 39 | 1.8 | 119.0 | 21 | 3.7 | +13 | +19.0 |
| 40 | 68 | 46 | 1.9 | 12.9 | 7 | 3.8 | + 7 | +14.5 |
| 41 | 73 | 47 | 1.3 | 164.0 | 19 | 2.2 | + 3 | +19.5 |
| 42 | 72 | 51 | 1.0 | 147.0 | 18 | 2.2 | + 4 | +18.0 |
| 43 | 73 | 48 | 1.2 | 147.0 | 18 | 2.2 | + 6 | +19.0 |
| 44 | 70 | 50 | 0.7 | 144.5 | 17 | 2.0 | + 2 | +17.0 |
| 45 | 59 | 49 | 1.4 | 35.7 | 5 | 0.7 | + 6 | + 5.0 |
| 46 | 63 | 46 | 2.0 | 70.0 | 7 | 0.7 | + 8 | + 8.5 |
| 47 | 59 | 41 | 1.4 | 85.3 | 18 | 3.8 | +11 | +13.0 |
| 48 | 65 | 39 | 1.6 | 164.0 | 25 | 3.8 | +12 | +21.0 |
| 49 | 66 | 40 | 1.1 | 162.0 | 18 | 2.0 | + 8 | +18.0 |
| 50 | 59 | 48 | 2.0 | 60.0 | 6 | 0.6 | +12 | + 8.0 |
| 51 | 53 | 52 | None | 18.0 | 3 | 0.5 | + 7 | + 2.5 |
| 52 | 44 | 40 | 0.2 | 22.8 | 4 | 0.7 | +15 | + 3.5 |
| 53 | 47 | 30 | 1.6 | 55.0 | 11 | 2.2 | +16 | +10.5 |
| 54 | 55 | 31 | 1.2 | 135.0 | 18 | 2.4 | +14 | +19.0 |
| 55 | 66 | 33 | $0.\bar{3}$ | 93. | 6 | $2.\bar{1}$ | Miss | +15. |
| 56 | 60 | 34 | 1.1 | 221.0 | 29 | 3.8 | Miss | +25.0 |
| 57 | 57 | 32 | $0.\bar{5}$ | 262.0 | 24 | $2.\bar{2}$ | Miss | +23. |
| 58 | 59 | 31 | 0.1 | 206.0 | 28 | 3.8 | + 7 | +23.0 |
| 59 | 57 | 31 | 0.1 | 192.0 | 27 | 3.8 | Miss | +23.0 |

| No. of Observations | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|
| 29 | 21.0 | 0.1 | 1.0 | 56.6 | 6.0 | W | 30.0 | Yes |
| 30 | 14.5 | 0.5 | 5.0 | 65.9 | 3.0 | NW | 11.3 | Yes |
| 31 | 28.5 | 7.0 | 7.0 | 59.4 | 2.0 | SE | 6.8 | Yes |
| 32 | 40.5 | 3.9 | 8.0 | 68.6 | 2.6 | N | 5.8 | Yes |
| 33 | 54.5 | 5.3 | 10.1 | 57.7 | 1.3 | C | 7.8 | Yes |
| 34 | 52.0 | 3.2 | 7.7 | 59.0 | 2.6 | N | 5.8 | No |
| 35 | 45.8 | 0.5 | 7.0 | 64.9 | 1.0 | C | 13.8 | No |
| 36 | Miss | Miss | Miss | 64.3 | 2.9 | N | 5.8 | Yes |
| 37 | Miss | Miss | Miss | 69.6 | 3.9 | NW | 8.5 | Yes |
| 38 | Miss | 0.2 | 3.1 | 42.7 | 3.1 | NW | 21.0 | No |
| 39 | Miss | 9.7 | 9.7 | 66.4 | 3.1 | NW | 18.8 | Yes |
| 40 | 42.8 | 3.1 | 7.6 | 69.3 | 3.6 | S | 28.8 | No |
| 41 | 53.3 | 4.1 | 9.9 | 60.0 | 1.3 | C | 25.0 | No |
| 42 | 53.8 | 4.1 | 9.4 | 61.6 | 3.1 | W | 11.8 | Yes |
| 43 | 56.3 | 3.7 | 9.3 | 59.6 | 2.9 | N | 11.3 | Yes |
| 44 | 53.5 | 3.6 | 9.0 | 62.6 | 8.1 | NW | 8.3 | No |
| 45 | 34.0 | 0.4 | 4.2 | 91.7 | 4.3 | W | 2.5 | Yes |
| 46 | 26.3 | 0.4 | 5.3 | 79.1 | 2.7 | N | 8.3 | Yes |
| 47 | 30.5 | 7.0 | 7.0 | 77.3 | 1.0 | C | 15.0 | Yes |
| 48 | 30.5 | 9.3 | 9.3 | 66.6 | 2.4 | NW | 20.0 | Yes |
| 49 | 54.5 | 3.8 | 9.3 | 68.7 | 1.4 | C | 7.5 | No |
| 50 | 24.0 | 0.4 | 5.1 | 77.3 | 2.4 | N | 6.8 | Yes |
| 51 | 13.3 | 0.1 | 3.1 | 98.0 | 4.4 | N | 3.1 | Yes |
| 52 | 11.8 | 0.4 | 3.9 | 96.4 | 4.0 | N | 1.7 | Yes |
| 53 | 20.5 | 2.6 | 5.0 | 87.1 | 1.9 | C | 1.4 | Yes |
| 54 | 40.5 | 4.2 | 9.3 | 74.7 | 1.7 | C | 5.5 | No |
| 55 | 47.0 | 3.2 | 6.8 | 60.0 | 3.1 | N | 17.8 | Yes |
| 56 | 62.0 | 5.5 | 10.8 | 59.0 | 0.6 | C | 8.0 | No |
| 57 | 67.0 | 6.0 | 11.0 | 64.3 | 0.9 | C | 7.3 | No |
| 58 | 70.0 | 10.2 | 10.2 | 65.7 | 1.6 | C | 6.8 | No |
| 59 | 69.0 | 5.3 | 10.1 | 64.6 | 0.9 | C | 5.8 | Yes |

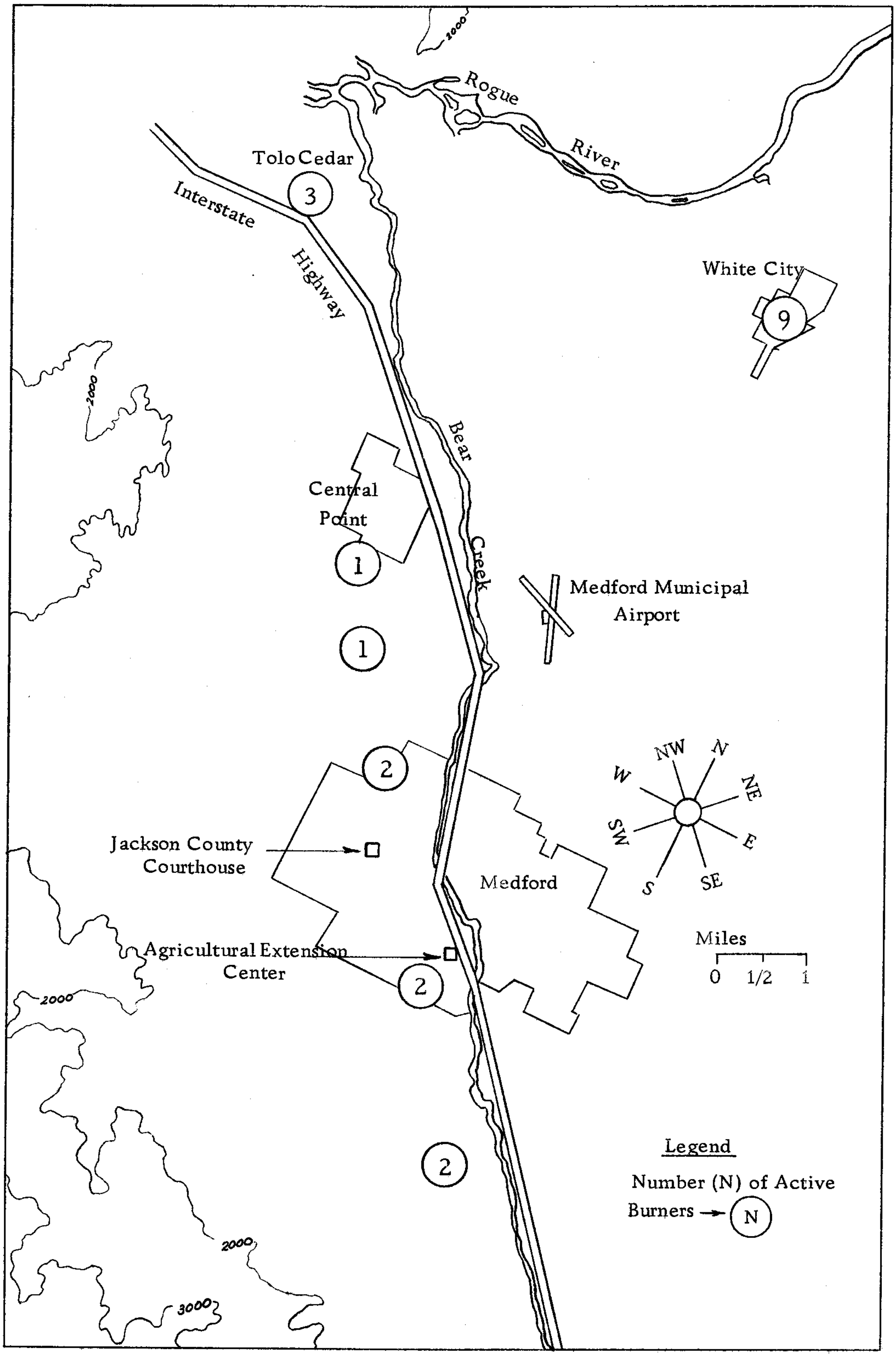
| No. of Observations | U | V | W |
|---|---|---|---|
| 29 | SI | | |
| 30 | | | |
| 31 | | | X |
| 32 | | | |
| 33 | | | |
| 34 | | | |
| 35 | | | |
| 36 | | | |
| 37 | | | |
| 38 | SI | | |
| 39 | | | |
| 40 | | | |
| 41 | | | |
| 42 | | | |
| 43 | | | |
| 44 | | .15 | |
| 45 | | | |
| 46 | | | |
| 47 | | | |
| 48 | | | |
| 49 | | | X |
| 50 | | | |
| 51 | | .09 | |
| 52 | SI | | |
| 53 | | | |
| 54 | | | |
| 55 | | | |
| 56 | | | |
| 57 | | | |
| 58 | | | X |
| 59 | | | |

| No. of Observation | Date | Day of Week | $C_1$ | $C_2$ | $C_3$ | A | B | D |
|---|---|---|---|---|---|---|---|---|
| 60 | 24 | Sat | 90.5 | 99.4 | 25.6 | 11.0 | +10.3 | 21 |
| 61 | 25 | Sun | 73.0 | 38. | Miss | 5.4 | + 3.1 | 16 |
| 62 | 26 | Mon | 57.1 | 83.4 | 23.9 | None | - 5.2 | 6 |
| 63 | 27 | Tues | 78.2 | 50.4 | 83.8 | 2.4 | + 0.1 | 9 |
| 64 | 28 | Wed | 69.0 | 78.3 | 39.8 | 4.5 | + 2.0 | 9 |
| 65 | 30 | Fri | 86.0 | 130.2 | 55.0 | 0.8 | - 4.2 | 6 |
| 66 | 31 | Sat | 25. | 80.2 | 23. | 5.0 | + 5.0 | 7 |

| No. of Observation | E | F | G | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|
| 60 | 54 | 33 | 0.9 | 147.0 | 18 | 2.2 | +11 | +18.0 |
| 61 | 55 | 39 | 1.4 | 60.5 | 11 | 2.0 | Miss | +10.0 |
| 62 | 53 | 47 | None | None | None | None | + 6 | + 1.0 |
| 63 | 53 | 44 | 0.2 | 40.0 | 4 | 0.4 | + 3 | + 6.0 |
| 64 | 54 | 45 | 0.3 | 62.5 | 5 | 0.4 | + 4 | + 7.5 |
| 65 | 52 | 46 | 0.3 | 12.9 | 3 | 0.7 | + 9 | + 2.0 |
| 66 | 48 | 41 | 0.2 | 71.0 | 16 | 3.6 | + 7 | +11.0 |

| No. of Observation | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|
| 60 | 61.5 | 4.1 | 9.9 | 72.4 | 1.6 | C | 4.3 | No |
| 61 | 44.5 | 3.0 | 5.6 | 75.3 | 0.7 | C | 5.3 | Yes |
| 62 | 20.5 | None | 1.5 | 89.4 | 1.6 | C | 10.0 | Yes |
| 63 | 15.0 | 0.3 | 3.8 | 95.7 | 2.3 | N | 4.0 | Yes |
| 64 | 17.8 | 0.4 | 5.0 | 95.7 | 1.6 | C | 10.0 | Yes |
| 65 | 8.8 | 0.3 | 3.7 | 97.3 | 2.1 | S | 3.6 | Yes |
| 66 | 19.5 | 5.0 | 5.0 | 95.6 | 1.3 | C | 0.3 | Yes |

| No. of Observation | U | V | W |
|---|---|---|---|
| 60 | | | |
| 61 | | T | |
| 62 | SI | | |
| 63 | | | X |
| 64 | | | |
| 65 | | | |
| 66 | | | |



2000
Rogue
River
Tolo Cedar
3
Interstate
Highway
White City
9
2000
Bear
Central
Point
1
Creek
Medford Municipal
Airport
1
2
NW
N
W
NE
SW
E
S
SE
Jackson County
Courthouse
Medford
Agricultural Extension
Center
2
Miles
0
1/2
1
2000
2
Legend
Number (N) of Active
Burners
N
2000
3000