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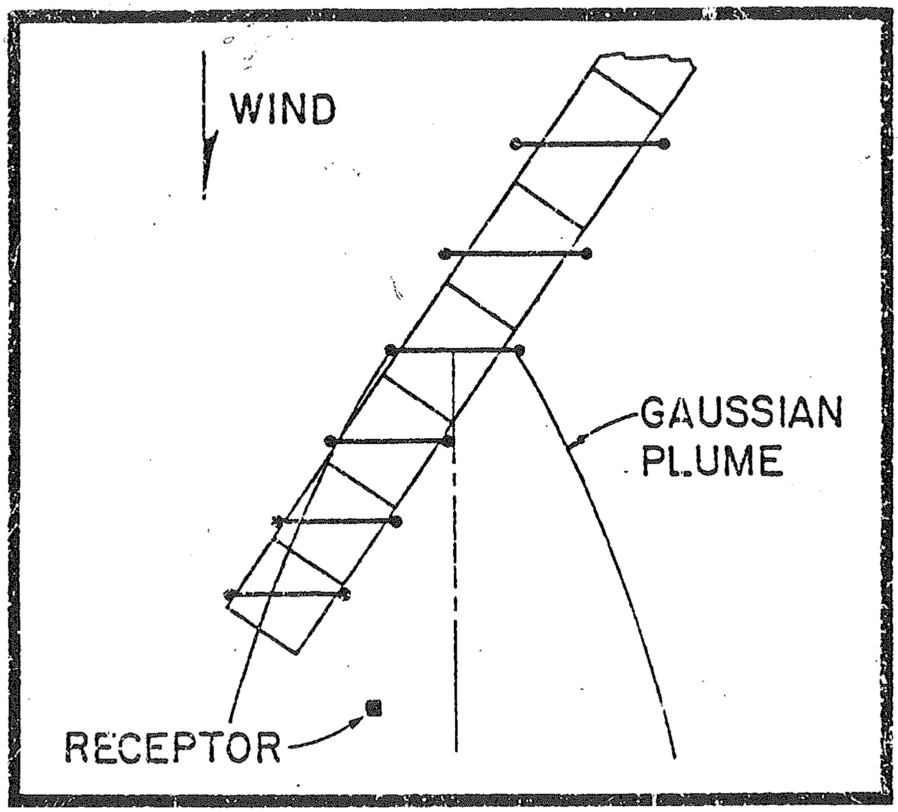
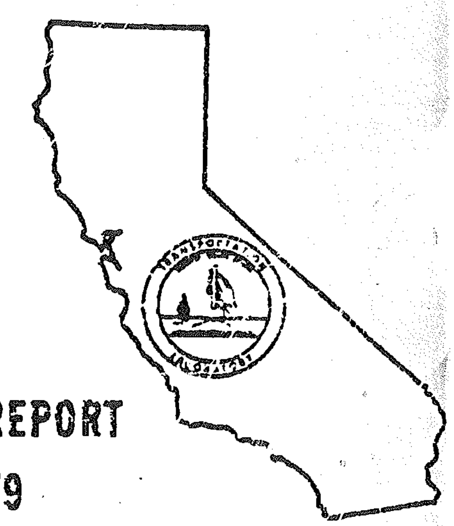
REPORT NO. FHWA/CA/TL-79/23

CALINE3 - A Versatile Dispersion Model For Predicting Air Pollutant Levels Near Highways And Arterial Streets





INTERIM REPORT

NOV. 1979

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

November 1979

FHWA No. A-8-46
TL No. 657296

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this interim research project report titled:

CALINE3
A VERSATILE DISPERSION MODEL FOR PREDICTING AIR POLLUTANT LEVELS NEAR HIGHWAYS AND ARTERIAL STREETS

Study Made by .... Enviro-Chemical Branch

Under the Supervision of .... Earl C. Shirley, P.E.
and Roy W. Bushey, P.E.

Principal Investigator .... Paul E. Benson, P.E.

Report Prepared by .... Paul E. Benson

Assisted by .... Edward C. Wong
Michael Van De Pol

Very truly yours,

Neal Andersen

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

Attachment

PEB:db

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Messrs. Edward Wong and Michael Van De Pol for their assistance on this project. Mr. Wong carried out the model sensitivity analysis and, with the assistance of Mr. Ray Baishiki (Office of Computer Systems), was responsible for the FORTRAN conversion of CALINE3 and much of the user instructions. Mr. Van De Pol conducted the complex verification analysis including comparisons between CALINE2 and CALINE3. The guidance received from Drs. Leonard Myrup and Daniel Chang of the University of California at Davis was also especially helpful, as was the report review by Messrs. Earl Shirley and Roy Bushey. Mrs. Marion Ivester is responsible for the excellent graphics contained in the report, and Ms. Darla Bailey for turning the numerous, illegible rough drafts into a readable, typewritten report.

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quanity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour(mph)	.4470	metres per second (m/s)
	feet per second(fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity(G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^2)
Force	pounds (lbs)	4.448	newtons(N)
	kips (1000 lbs)	4.448	newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds(ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1.356	joules (J)
Bending Moment or Torque	inch-pounds(ft-lbs)	.1130	newton-metres (Nm)
	foot-pounds(ft-lbs)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

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1. INTRODUCTION

CALINE3 is a third generation line source air quality model developed by the California Department of Transportation. It is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadway.

The purpose of the model is to assess air quality impacts near transportation facilities in what is known as the micro-scale region. Given source strength, meteorology, site geometry, and site characteristics, the model can reliably predict pollutant concentrations for receptors located within 150 meters of the roadway. At present, the model can handle only inert pollutants such as carbon monoxide, or particulates. It is anticipated that nitrogen dioxide predictive capabilities will be added to the model within the next year.

Historically, the CALINE series of models required relatively minimal input from the user. Spatial and temporal arrays of wind direction, wind speed and diffusivity were not used by the models. While CALINE3 has several added inputs over its predecessor, CALINE2, it must still be considered an extremely easy model to implement. More complex models are unnecessary for most applications because of the uncertainties in estimating emission factors and traffic volumes for future years. As a predictive tool, CALINE3 is well balanced in terms of the accuracy of state-of-the-art emissions and traffic models, and represents a significant improvement over CALINE2 in this respect. The new model also possesses much greater flexibility than CALINE2 at little cost to the user in terms of input complexity.

This report should help the potential user of CALINE3 to understand and apply the model. Users should become thoroughly familiar with the workings of the model and, particularly, its limitations. This knowledge will aid them in deciding when and how to use CALINE3. Also, users should become familiar with the response of the model to changes in various input parameters. This information is contained in the sensitivity analysis portion of this report.

The results of a verification study using three separate data bases are also contained in this report. Dramatic improvements over CALINE2 are shown, particularly for parallel winds and stable atmospheric conditions. User instructions have been added along with several examples of CALINE3 applications which illustrate the variety of situations for which the model can be used.

2. BACKGROUND

In response to the National Environmental Policy Act of 1969, Caltrans published its first line source dispersion model for inert gaseous pollutants in 1972(1). Model verification using the rudimentary field observations then available was inconclusive.

In 1975, the original model was replaced by a second generation model, CALINE2(2). The new model was able to compute concentrations for depressed sections and for winds parallel to the highway alignment. The two models were compared using 1973 CO bag sampling data from Los Angeles with CALINE2 proving superior.

Sometime after the dissemination of CALINE2, users began to report suspiciously high predictions by the model for stable, parallel wind conditions. As a result, a more complete verification of the model was undertaken by Caltrans using the 1974-75 Caltrans Los Angeles Data Base(3), and the 1975 GM Sulfate Experiment Data Base(4). Comparison of predicted and measured results showed that the predicted CO concentrations near the roadway were two to five times greater than measured values for stable, parallel wind conditions. An independent study by Noll in 1977(5) concluded that CALINE2 overpredicted for parallel winds by an average of 66% for all stabilities.

Overpredictions by CALINE2 for the stable, parallel wind case were particularly significant. This configuration was usually selected as the worst case condition for predicting highway impact on air quality in the microscale region. Thus, beneficial highway projects might have been delayed or cancelled on the basis of inaccurate results from CALINE2.

Inadequacies in the model also needed rectification. The inability to specify line source length and ground roughness severely limited the number of situations in which the model could be properly applied. Also, predicting impacts from multiple sources required a series of runs with varying receptor distances. Such an unwieldy procedure could lead to erroneous results.

In view of the inaccuracies and inadequacies of CALINE2, the model assumptions and computational methods were reviewed with the idea of revising the model. Since, in some cases, the mathematical approach in CALINE2 emphasized convenience and computational efficiency rather than a rigorous treatment, it became apparent that revisions would not suffice and a completely new model was needed. The new model would retain the Gaussian formulation so that input requirements could be kept at a minimum. However, the highway would be modeled as a series of finite line sources positioned perpendicular to the wind direction, as opposed to the series of virtual point sources used by CALINE2. Also, it was felt that new vertical dispersion curves were needed. The curves used by CALINE2 were modified versions of Turner's curves(6). These curves were derived for averaging times of 10 minutes or less and extremely smooth terrain. Both of these factors contributed to the overpredictions for one-hour urban CO concentrations. Recent research by Caltrans(7) concluded that the amount of vertical mixing near the roadway increased as wind speed decreased. These findings were combined with more recently developed dispersion curves published by Pasquill in 1974(8). Adjustments for averaging time and surface roughness also were included in the dispersion curve algorithms.

3. CONCLUSIONS AND RECOMMENDATIONS

The comparisons of CALINE2 and CALINE3 made in the Verification Analysis portion of this report clearly demonstrate the improved performance of the new model. It is concluded that the new algorithms contained in CALINE3 represent the dispersion process near highways in a more realistic way than did CALINE2. In addition, the greater flexibility of the new model makes it adaptable to many modeling applications not appropriate for CALINE2. Finally, CALINE3 does not require additional computational time over CALINE2 for equivalent applications. For these reasons, it is recommended that CALINE3 replace CALINE2 as the official line source air quality model used by Caltrans.

There are some aspects of CALINE3 on which further research is recommended:

1. The residence time hypothesis needs to be studied for vehicle speeds under 30 miles/hour.

2. Verification of the model for intersection analysis must be carried out.

3. Validation of the deposition and settling velocity components of the model is needed.

4. Study of worst case meteorology as a function of land use and geography is needed for more accurate evaluation of multi-hour averages.

5. NO_2 predictive capabilities must be added to the model and verified.

4. IMPLEMENTATION

The CALINE3 program described in this report is available for use by state personnel on both the Caltrans statewide time-share computer system, TENET, and the Teale Data Center IBM 370/168. The TENET version (BASIC Language) can be accessed through the environmental sub-system: "5;ENV;SYS", Program No. 21. The job control language required to access the IBM version (FORTRAN Language) is given in the User Instruction section of this report. This version has been modified to conform with American National Standard FORTRAN. A two day training course on the use of the model is planned for state personnel sometime during 1980.

An abbreviated version of the model for use on HP-67/97 and TI-59 programmable calculators is provided in this report for implementation under circumstances where standard computer facilities are unavailable.

5. MODEL DESCRIPTION

5.1 Gaussian Element Formulation

CALINE3 divides individual highway links into a series of elements from which incremental concentrations are computed and then summed to form a total concentration estimate for a particular receptor location (see Fig. 1). The receptor distance is measured along a perpendicular from the receptor to the highway centerline. The first element is formed at this point as a square with sides equal to the highway width. The lengths of subsequent elements are described by the following formula:

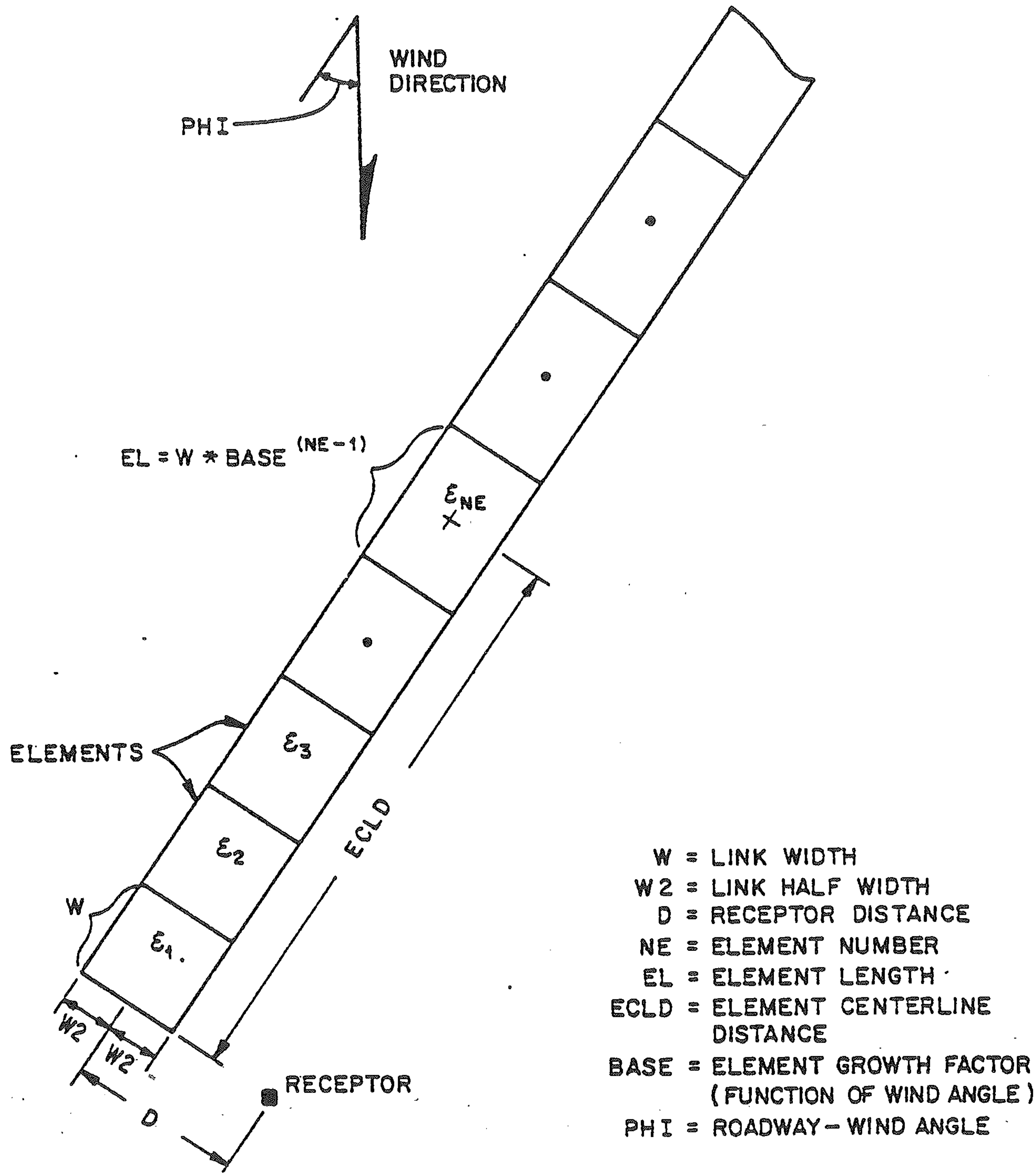
$$EL = W*BASE^{(NE-1)}$$

Where,
- EL = Element Length
- W = Highway Width
- NE = Element Number
- BASE = Element Growth Factor

$$PHI<20°, \quad BASE=1.1$$
$$20° \le PHI<50°, \quad BASE=1.5$$
$$50° \le PHI<70°, \quad BASE=2.0$$
$$70° \le PHI, \quad BASE=4.0$$

(Note: Capitalized variables shown in text and figures are identical to those used in the computer coding.)

Thus, as element resolution becomes less important with distance from the receptor, elements become larger to permit efficiency in computation. The choice of the element growth factor as a function of roadway-wind angle (PHI) range represents a good



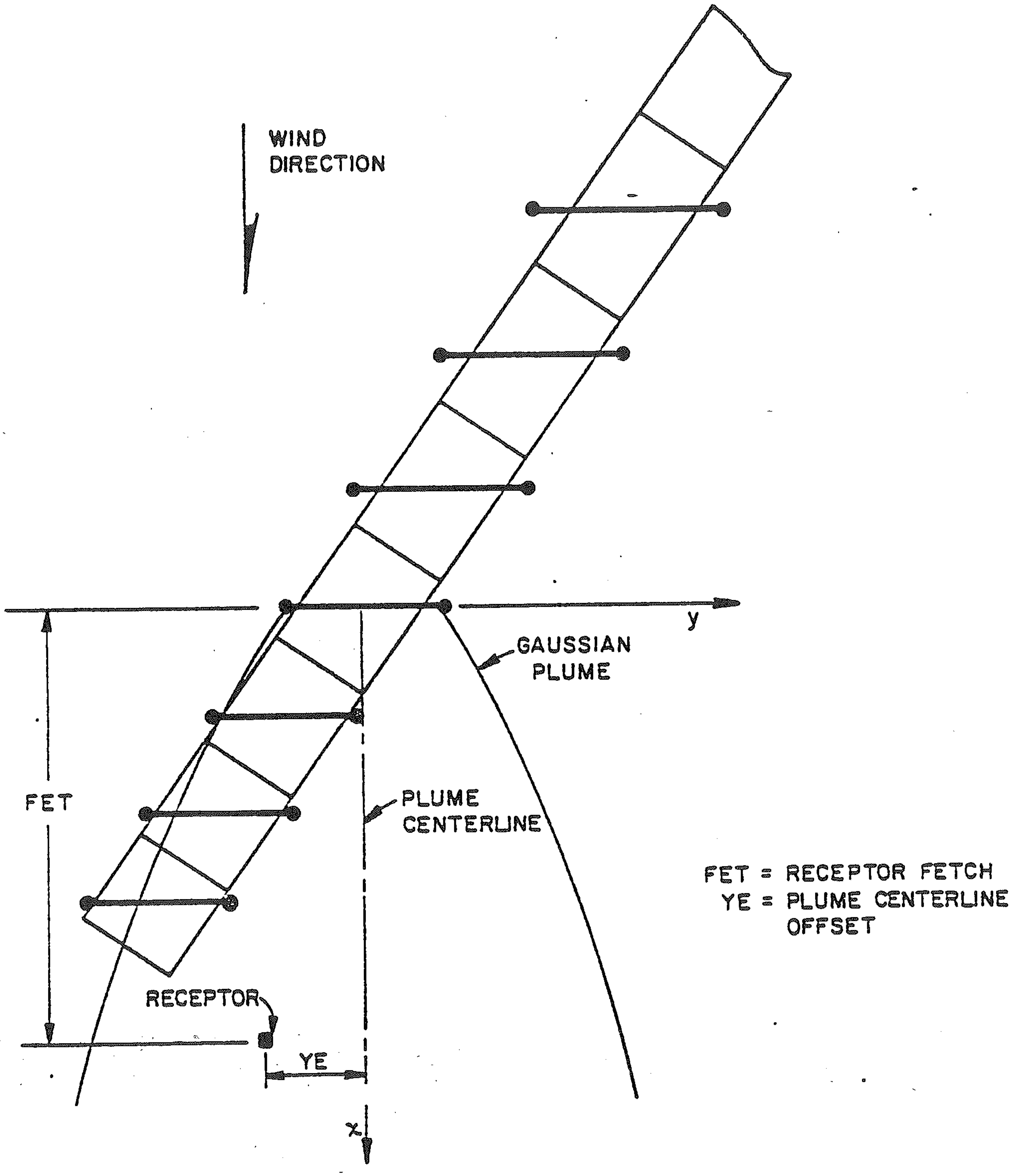
ELEMENT SERIES USED BY CALINE3

FIGURE 1

compromise between accuracy and computational efficiency. Finer initial element resolution is unwarranted because the vertical dispersion curves used by CALINE3 have been calibrated for the link half-width (W2) distance from the element centerpoint.

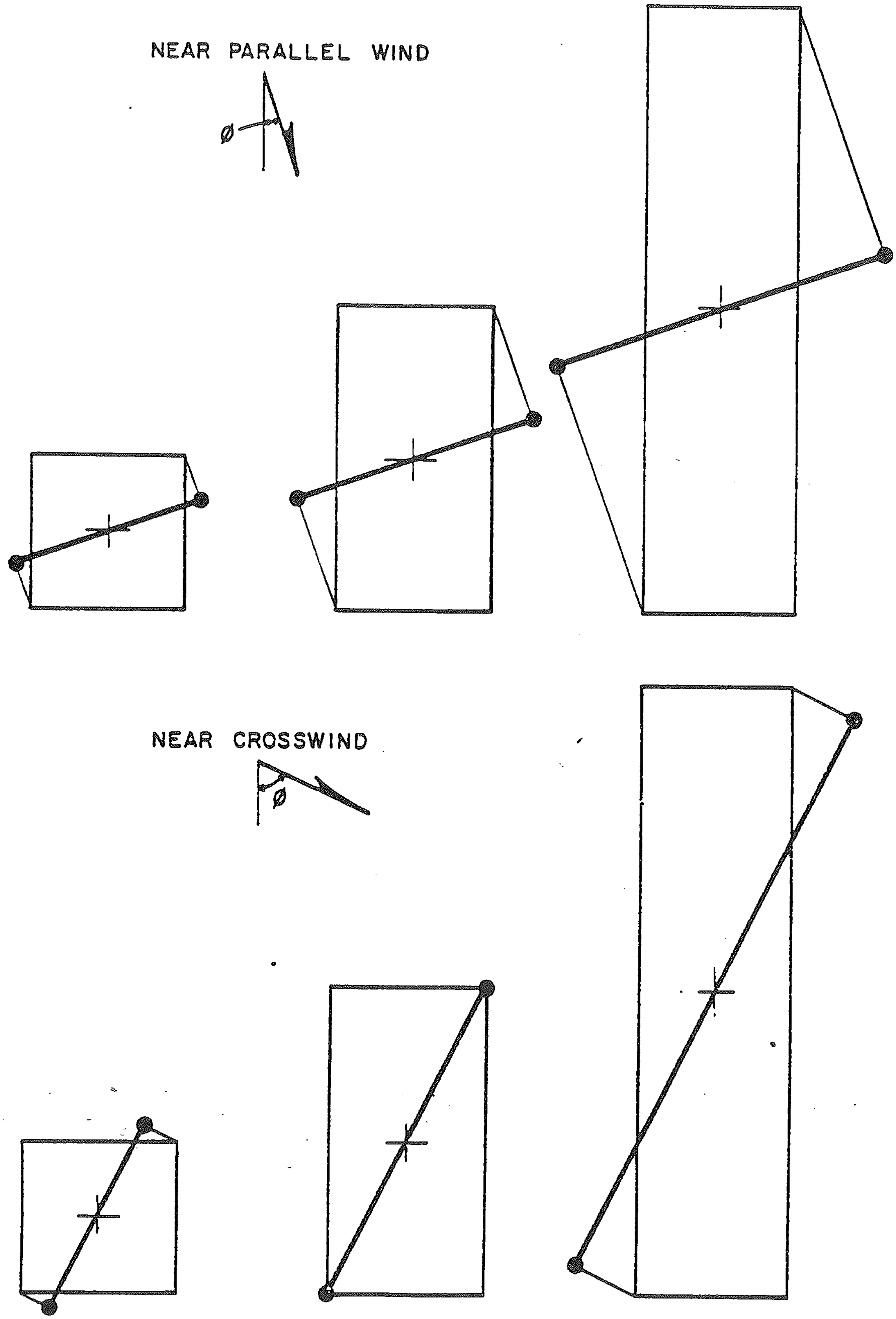
Each element is modeled as an "equivalent" finite line source (EFLS) positioned normal to the wind direction and centered at the element midpoint (see Fig. 2). A local x-y coordinate system aligned with the wind direction and originating at the element midpoint is defined for each element. The emissions occurring within an element are assumed to be released along the EFLS representing the element. The emissions are then assumed to disperse in a Gaussian manner downwind from the element. The length and orientation of the EFLS are functions of the element size and the angle (PHI,ϕ) between the average wind direction and highway alignment (see Fig. 3). Values of PHI=0 or PHI=90 degrees are altered within the program an insignificant amount to avoid division by zero during the EFLS trigonometric computations.

In order to distribute emissions in an equitable manner, each element is divided into five discrete sub-elements represented by corresponding segments of the EFLS (see Figs. 4 & 5). The use of five sub-elements yields reasonable continuity to the discrete element approximation used by the model while not excessively increasing the computational time. The source strength for the segmented EFLS is modeled as a step function whose value depends on the sub-element emissions. The emission rate/unit area is assumed to be uniform throughout the element for the purposes of computing this step function. The size and location of the sub-elements are a function of element size and wind angle (see Fig. 6).



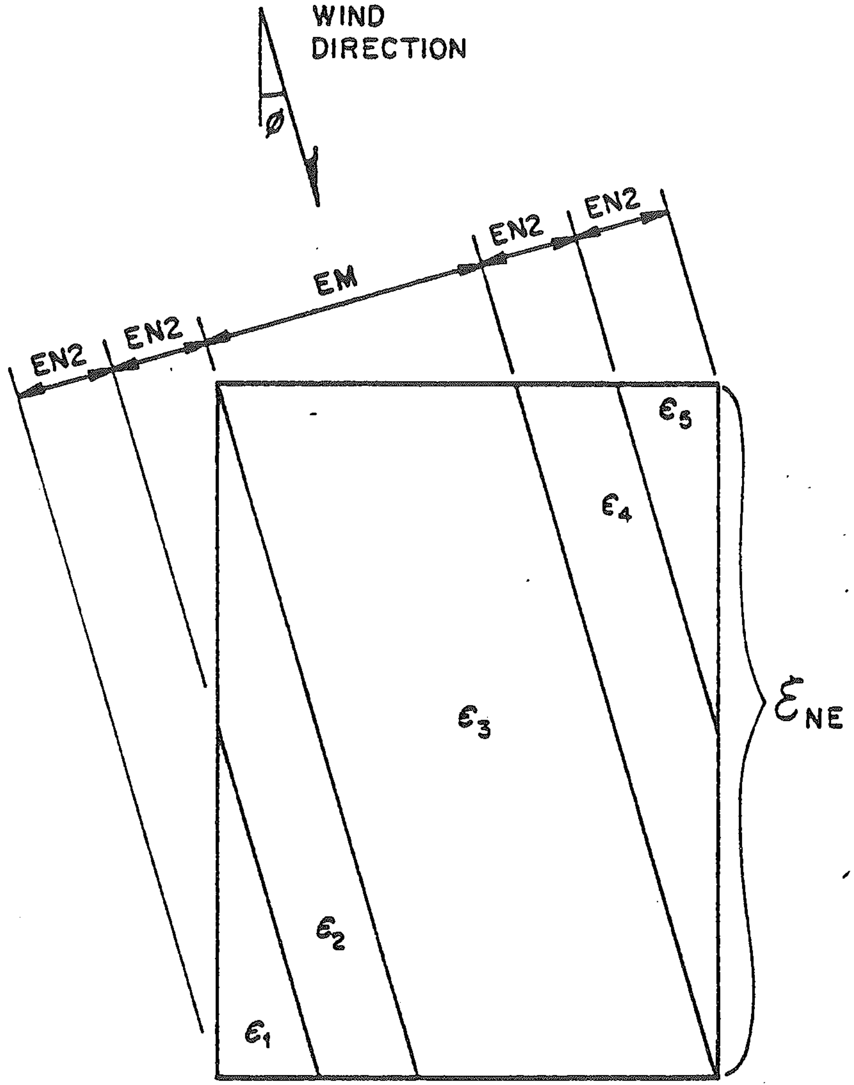
ELEMENT SERIES REPRESENTED BY
SERIES OF EQUIVALENT FINITE LINE SOURCES

FIGURE 2



EQUIVALENT FINITE LINE SOURCE REPRESENTATION FOR VARIOUS ELEMENT SIZES AND WIND ANGLES

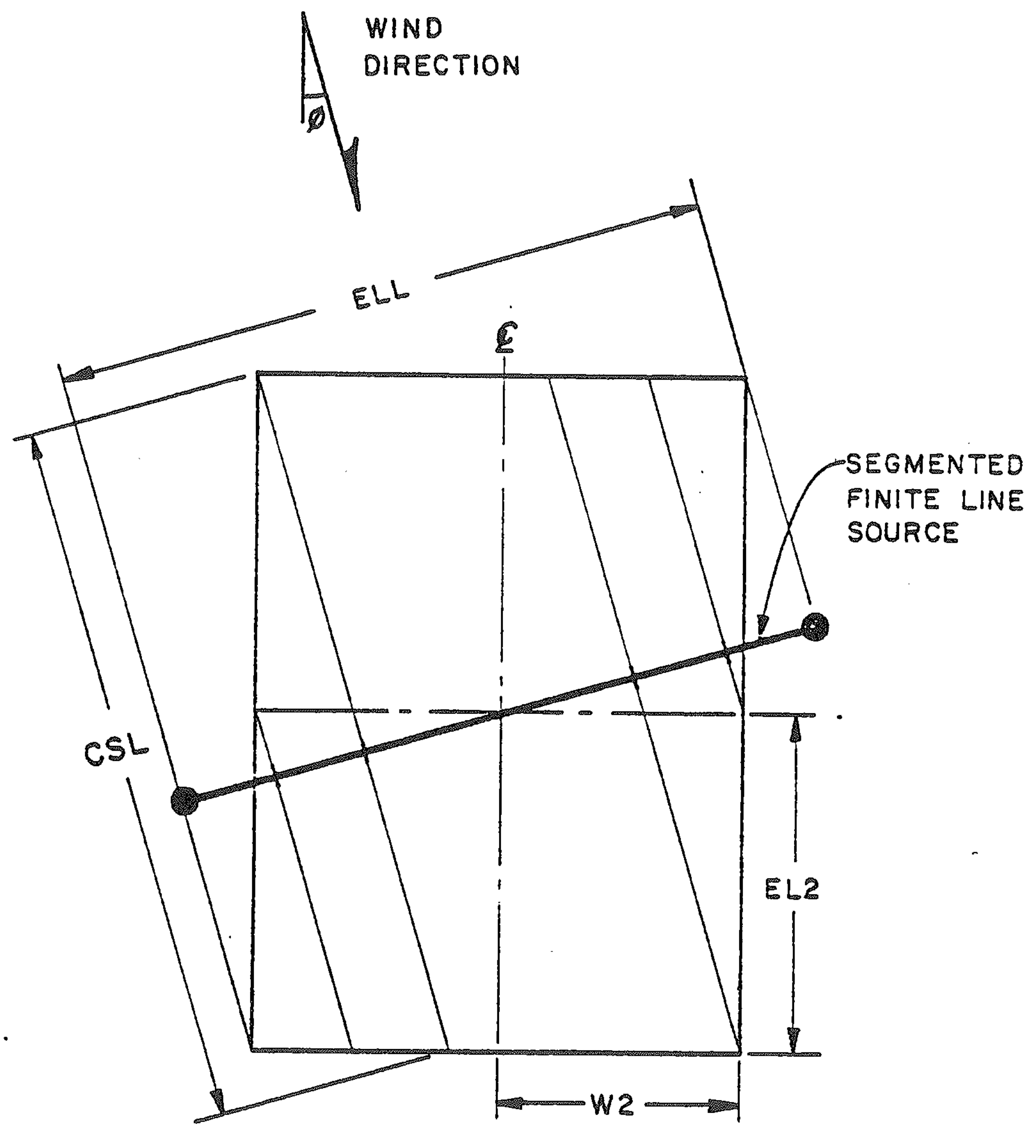
FIGURE 3



$\epsilon_1 \rightarrow \epsilon_5$ = SUB-ELEMENTS
EM, EN2 = SUB-ELEMENT WIDTHS

CALINE3 SUB-ELEMENTS

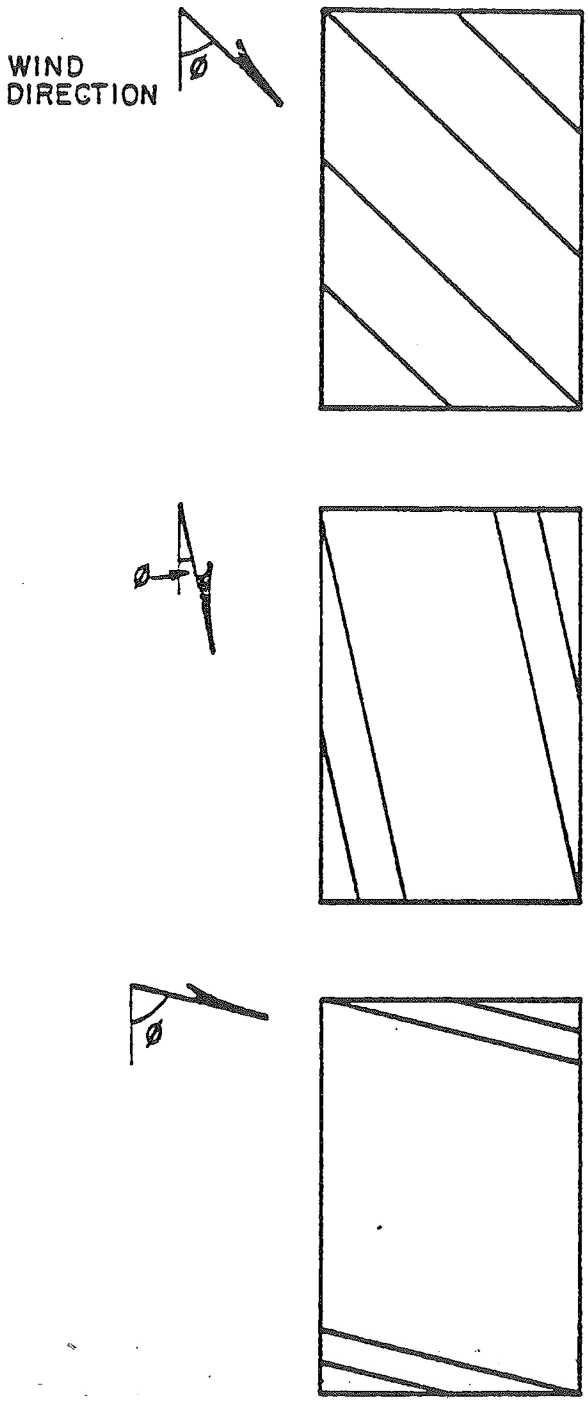
FIGURE 4



ELL = EQUIVALENT LINE LENGTH
CSL = CENTRAL SUB-ELEMENT LENGTH

CALINE3 FINITE LINE SOURCE
ELEMENT REPRESENTATION

FIGURE 5



SUB-ELEMENT CONSTRUCTION FOR VARIOUS WIND ANGLES

FIGURE 6

Downwind concentrations from the element are modeled using the crosswind finite line source (FLS) Gaussian formulation. Consider the receptor concentration attributable to an FLS segment of length dy shown in Figure 7:

$$dC = \frac{q\,dy}{2\pi u \sigma_y \sigma_z} \left[\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\right] \left\{\exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right]\right\}$$

Where,

dC = Incremental Concentration

q = Lineal Source Strength

u = Wind Speed

H = Source Height

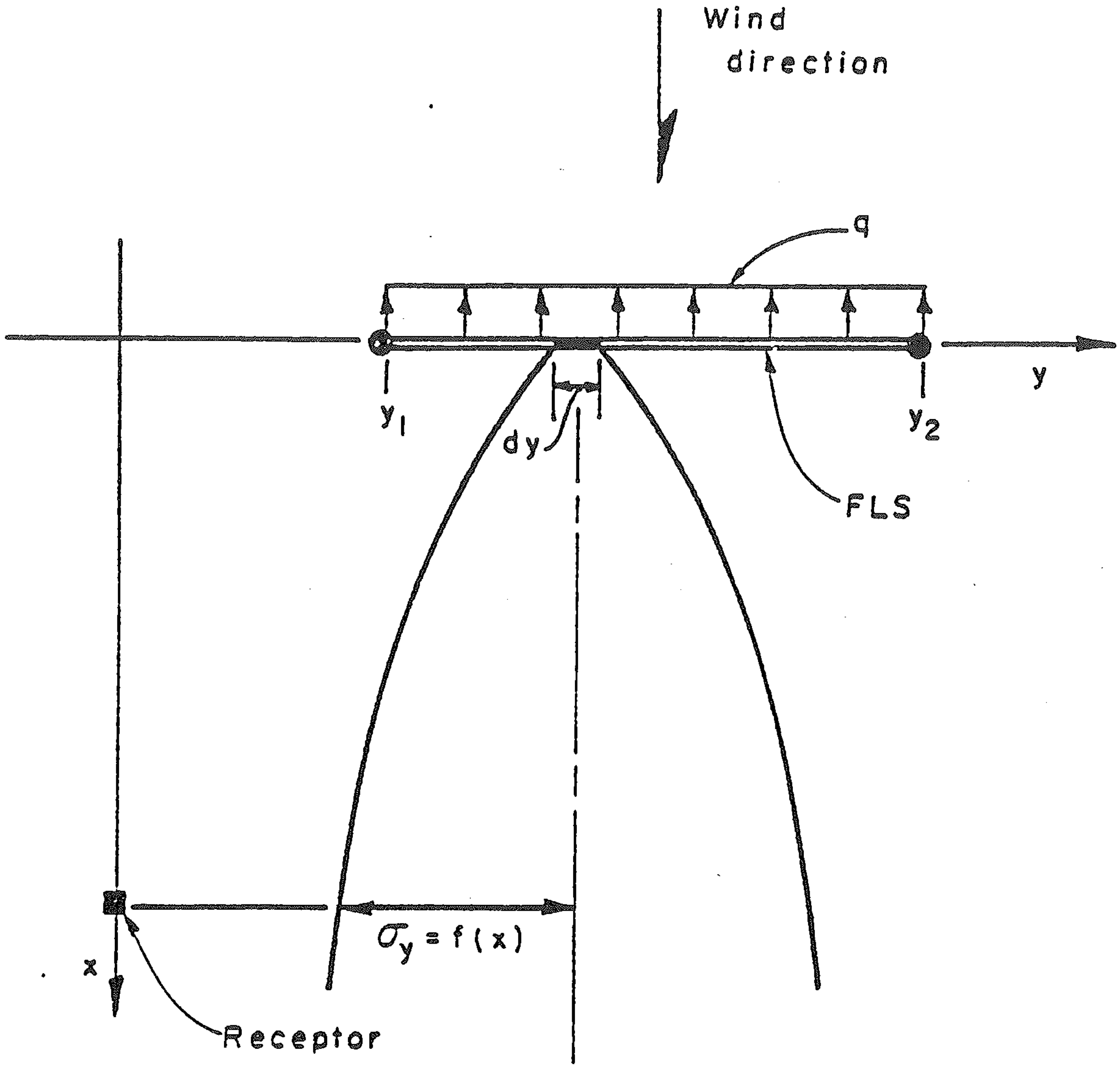
σ_y, σ_z = Horizontal and Vertical Dispersion Parameters

Since σ_z is constant with respect to y, let:

$$A = \exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right]$$

Integrating over the FLS length yields:

$$C = \frac{Aq}{2\pi u \sigma_y \sigma_z} \int_{y_1}^{y_2} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) dy$$



q = UNIFORM LINE SOURCE STRENGTH

σ_y = HORIZONTAL DISPERSION PARAMETER

GENERALIZED FINITE LINE SOURCE (FLS)

FIGURE 7

Note that σ_y and σ_z are functions of x, not y. Substituting $p=y/\sigma_y$ and $dp=dy/\sigma_y$:.

$$C = \frac{Aq}{2\pi u \sigma_y \sigma_z} \int_{y_1/\sigma_y}^{y_2/\sigma_y} \exp\left(\frac{-p^2}{2}\right) \sigma_z \, dp$$

Backsubstituting for A and removing σ_y from the integral leaves:

$$C = \frac{q}{2\pi \sigma_z u} \left\{ \exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right] \right\} \int_{y_1/\sigma_y}^{y_2/\sigma_y} \exp\left(\frac{-p^2}{2}\right) dp$$

This can be rewritten as:

$$C = \frac{q}{\sqrt{2\pi}\, \sigma_z u} \left\{ \exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right] \right\} \cdot PD$$

Where,

$$PD = \frac{1}{\sqrt{2\pi}} \int_{y_1/\sigma_y}^{y_2/\sigma_y} \exp\left(\frac{-p^2}{2}\right) dp = \text{Normal Probability Density Function}$$

CALINE3 computes receptor concentrations by approximating the crosswind FLS equation in the following manner (see Fig. 8):

$$C = \frac{1}{\sqrt{2\pi}U} * \sum_{i=1}^{n} \left\{ \frac{1}{SGZ_i} * \sum_{k=-CNT}^{CNT} \left[\exp\left(\frac{-(Z-H+2*k*L)^2}{2*SGZ_i^2} \right) + \exp\left(\frac{-(Z+H+2*k*L)^2}{2*SGZ_i^2} \right) \right] * \sum_{j=1}^{5} (WT_j * QE_i * PD_{ij}) \right\}$$

Where,

n = Total number of elements

CNT = Number of multiple reflections required for convergence

U = Wind speed

L = Mixing height (MIXH in coding)

SGZ_i = σ_z as f(x) for ith element

QE_i = Central sub-element lineal source strength for ith element

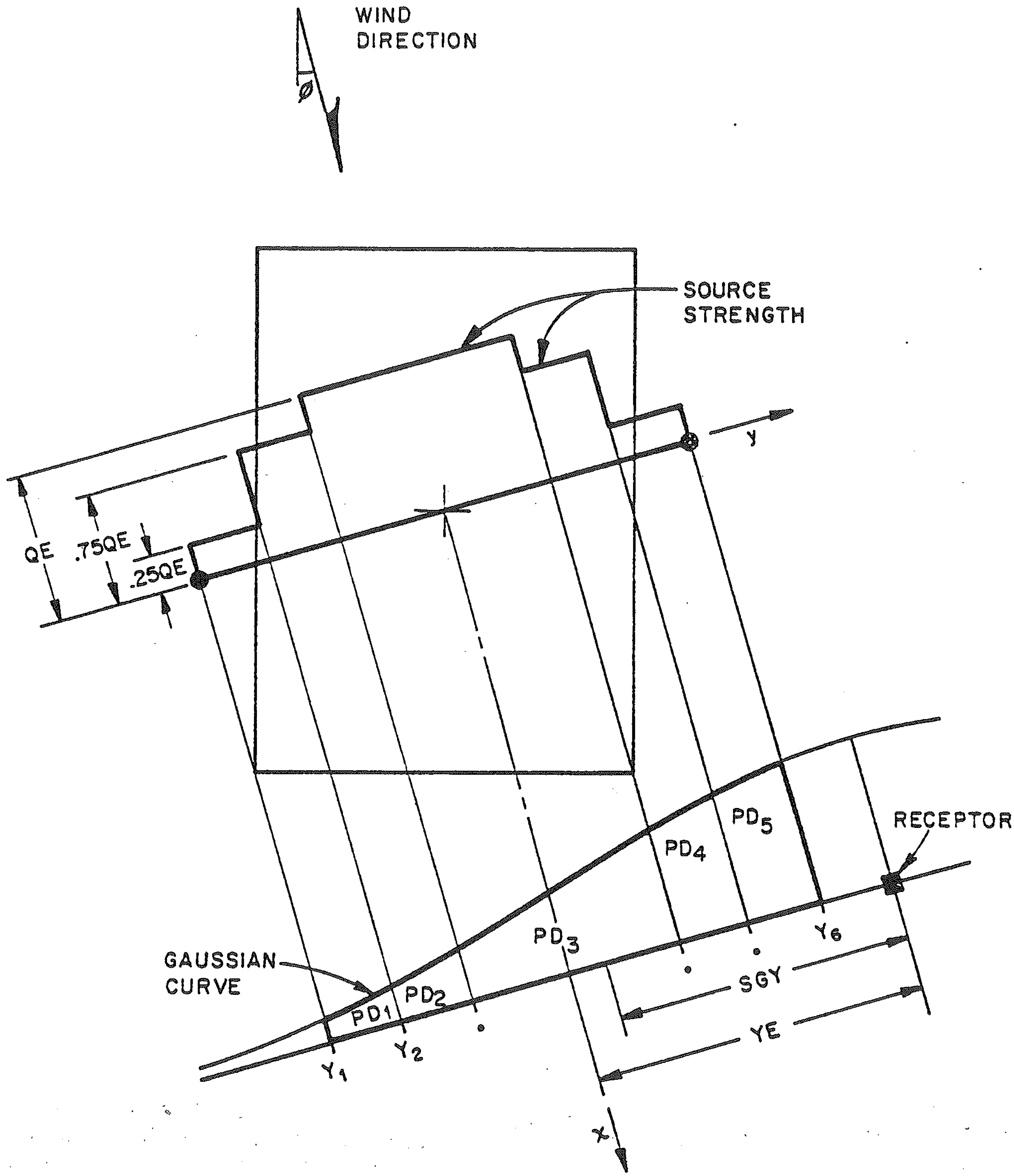
WT_j = Source strength weighting factor for jth sub-element (WT_1 = 0.25, WT_2 = 0.75, ...)

$$PD_{ij} = \frac{1}{\sqrt{2\pi}} \int_{\frac{Y_j}{SGY_i}}^{\frac{Y_{j+1}}{SGY_i}} \exp\left(\frac{-p^2}{2}\right) dp$$

Y_j, Y_{j+1} = Offset distances for jth sub-element

SGY_i = σ_y as f(x) for ith element

PD_{ij} is calculated by use of a fifth order polynomial approximation(9). Note the addition of multiple reflection terms represented by non-zero k indices to account for restricted mixing height (L).



QE = EQUIVALENT LINE SOURCE STRENGTH
PD = PROBABILITY DENSITY
SGY = HORIZONTAL DISPERSION PARAMETER
YE = PLUME CENTERLINE OFFSET

CALINE3 INTEGRATED FINITE LINE SOURCE AND SUB-ELEMENT MODEL

FIGURE 8

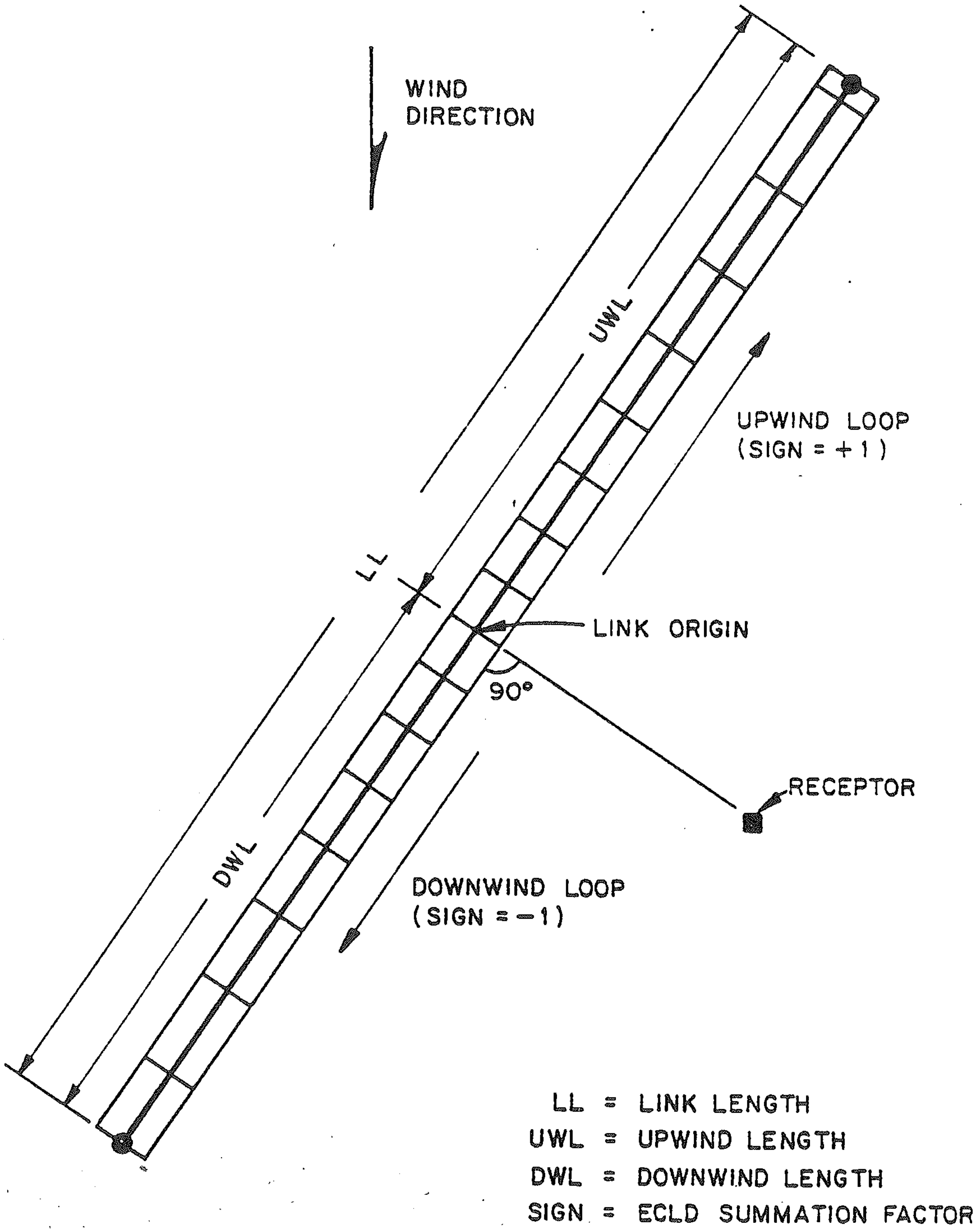
The source strength weighting factor (WT_j) adjusts the central sub-element lineal source strength measured with respect to the y-axis (QE) to the mean lineal source strength for each peripheral sub-element. Because of the uniform width of the peripheral sub-elements (EN2) and the assumption of uniform emissions over the element, $q=0$ @ $y=Y_1$, $q=QE/2$ @ $y=Y_2$, $q=QE$ @ $y=Y_3$, etc.

Therefore,

$$WT_1 * QE = WT_5 * QE = (QE/2+0)/2 = 0.25\ QE$$
$$WT_2 * QE = WT_4 * QE = (QE+QE/2)/2 = 0.75\ QE$$

The element summation of the FLS equation is actually initiated twice for each highway link specified by the user (see Fig. 9). The computation takes place first in the upwind direction, ending when the element limits go beyond the upwind length (UWL) for the link. The length of the last element is modified to conform with the link endpoint.

The program then proceeds in the downwind direction until the downwind length (DWL) is exceeded. As soon as a negative value of fetch (FET) is encountered, the program automatically concludes the downwind loop computations. If a receptor is located within an element or downwind from part of an element, only the upwind portion of the element is used to determine the source strength.



CALINE3 LINK - ELEMENT REPRESENTATION

FIGURE 9

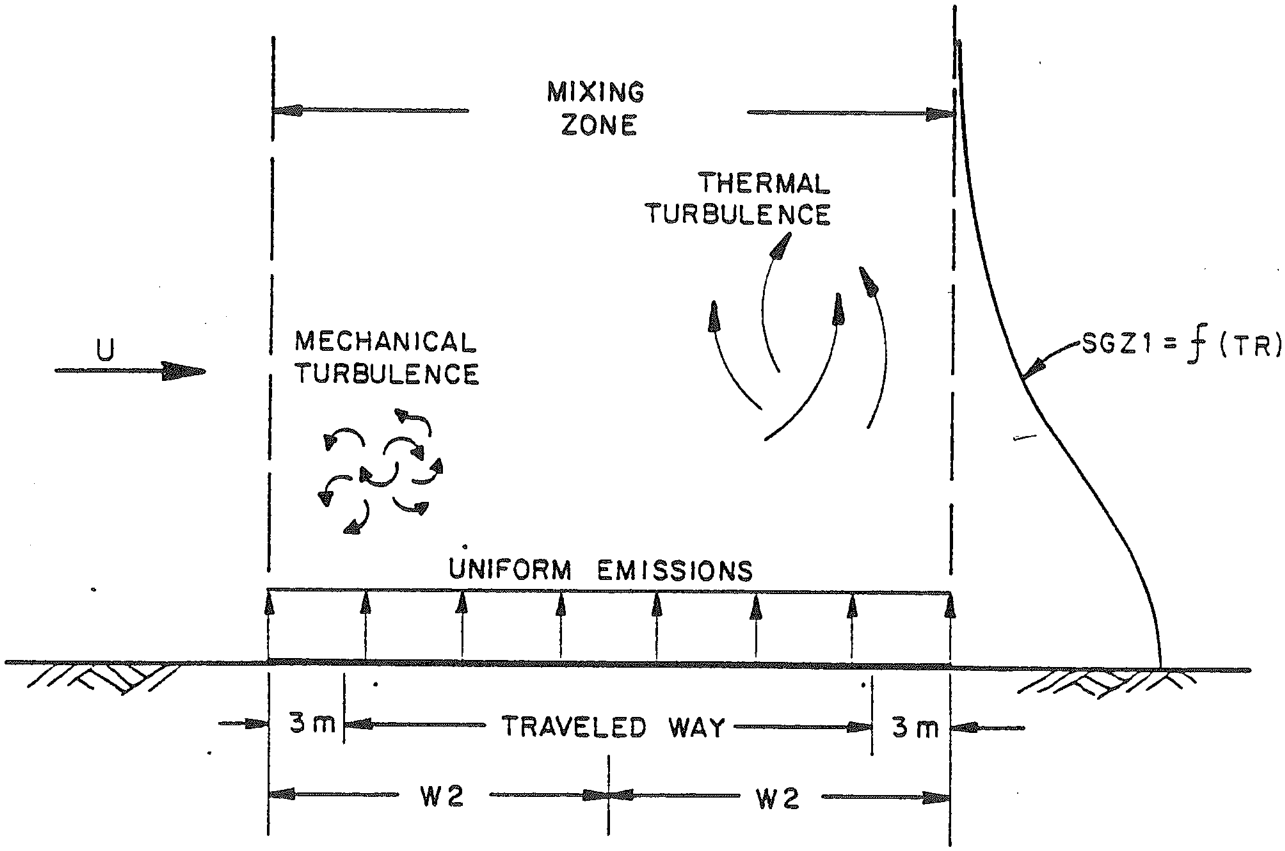
5.2 Mixing Zone Model

CALINE3 treats the region directly over the highway as a zone of uniform emissions and turbulence. This is designated as the mixing zone, and is defined as the region over the traveled way (traffic lanes - not including shoulders) plus three meters on either side (see Fig. 10). The additional width accounts for the initial horizontal dispersion imparted to pollutants by the vehicle wake effect.

Within the mixing zone, the mechanical turbulence created by moving vehicles and the thermal turbulence created by hot vehicle exhaust is assumed to predominate near the ground. Evidence indicates that this is a valid assumption for all but the most unstable atmospheric conditions(7). Since traffic emissions are released near the ground level and model accuracy is most important for neutral and stable atmospheric conditions, it is reasonable to model initial vertical dispersion (SGZ1) as a function of the turbulence within the mixing zone.

Analyses by Caltrans of the Stanford Research Institute(10) and General Motors(4) data bases indicate that SGZ1 is insensitive to changes in traffic volume and speed within the ranges of 4,000 to 8,000 vehicles/hr and 30 to 60 mph(7).

This may be due in part to the offsetting effects of traffic speed and volume. Higher volumes increase thermal turbulence but reduce traffic speed, thus reducing mechanical turbulence. For the range of traffic conditions cited, mixing zone turbulence may be considered a constant. However, pollutant residence time within the mixing zone, as dictated by the wind speed, significantly affects the amount of vertical



SGZ1 = INITIAL VERTICAL DISPERSION PARAMETER
TR = MIXING ZONE RESIDENCE TIME

CALINE3 MIXING ZONE

FIGURE 10

mixing that takes place within the zone. A distinct linear relationship between SGZ1 and residence time was exhibited by the two data bases studied.

CALINE3 arbitrarily defines mixing zone residence time as:

$$TR = W2/U$$

Where, $W2$ = Highway half-width
U = Wind speed

This definition is independent of wind angle and element size. It essentially provides a way of making the EFLS model compatible with the actual two-dimensional emissions release within an element. For oblique winds and larger elements, the plume is assumed to be sufficiently dispersed after traveling a distance of W2 such that the mixing zone turbulence no longer predominates.

The equation used by CALINE3 to relate SGZ1 to TR is:

$$\underset{(m)}{SGZ1} = 1.8 + 0.11 * \underset{(secs.)}{TR}$$

This was derived from the General Motors Data Base. It is adjusted in the model for averaging times other than 30 minutes by the following power law(11):

$$SGZ1_{ATIM} = SGZ1_{30} * (ATIM/30)^{0.2}$$

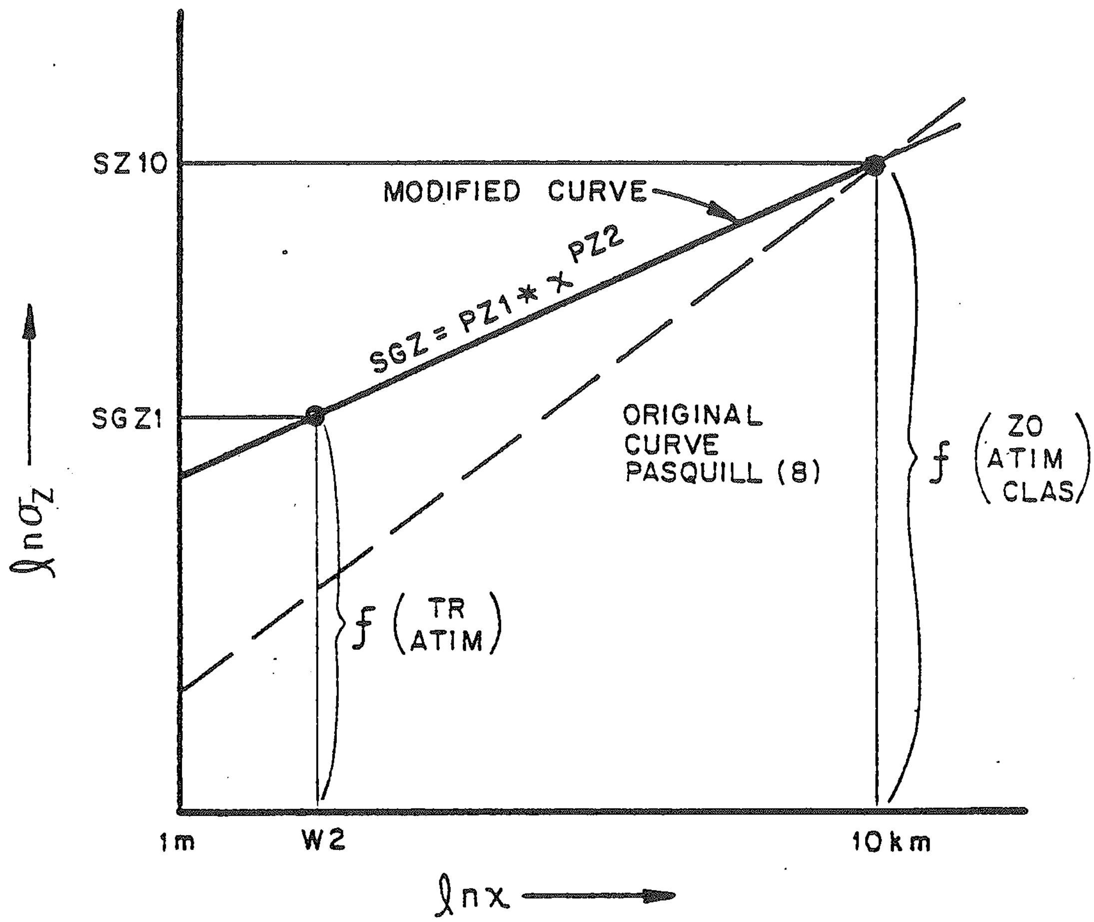
Where, ATIM = Averaging time (minutes)

The value of SGZ1 is considered by CALINE3 to be independent of surface roughness and atmospheric stability class. The user should note that SGZ1 accounts for all the enhanced dispersion over and immediately downwind of the roadway. Thus, the stability class used to run the model should be representative of the upwind or ambient stability without any additional modifications for traffic turbulence.

5.3 Vertical Dispersion Curves

The vertical dispersion curves used by CALINE3 are formed by using the value of SGZ1 from the mixing zone model, and the value of σ_z at 10 kilometers (SZ10) as defined by Pasquill(8). In effect, the power curve approximation suggested by Pasquill is elevated near the highway by the intense mixing zone turbulence (see Fig. 11). The significance of this added turbulence to plume growth lessens with increased distance from the source, though, in theory, it will never disappear. Extrapolated σ_z curves measured out to distances of 150 meters from the highway centerline under stable conditions for both the GM and SRI data bases intersect the Pasquill curves at roughly 10 kilometers. Beyond this point the power curve approximation to the true Pasquill curve, which is actually concave to the ℓnx axis, becomes increasingly inaccurate. Thus, the model should not be used for distances greater than 10 kilometers. As will be seen in the sensitivity analysis, contributions from elements greater than 10 kilometers from the receptor are insignificant even under the most stable atmospheric conditions.

For a given set of meteorological conditions, surface roughness (Z0) and averaging time (ATIM), CALINE3 uses the same vertical dispersion curve for each element within a highway link. This is possible since SGZ1 is always defined as occurring at a



ZO = AERODYNAMIC ROUGHNESS
ATIM = AVERAGING TIME
CLAS = STABILITY CLASS
TR = MIXING ZONE RESIDENCE TIME
x = PLUME CENTERLINE AXIS
σ_z = VERTICAL DISPERSION PARAMETER

MODIFIED VERTICAL DISPERSION CURVE – CALINE3

FIGURE 11

distance W2 downwind from the element centerpoint. SZ10 is adjusted for Z0 and ATIM by the following power law factors(11):

$$SZ10_{ATIM,Z0} = SZ10*(ATIM/3)^{0.2}*(Z0/10)^{0.07}$$

Where, ATIM = Averaging time (minutes)
Z0 = Surface roughness (cm)

Table 1 contains recommended values of Z0 for representative land use types(12).

The vertical dispersion of CO predicted by the model can be confined to a shallow mixed layer by means of the conventional Gaussian multiple reflection formulation(6). This capability was included in the model to allow for analysis of low traffic flow situations occurring during extended nocturnal low level inversions. Surprisingly high 8 hour CO averages have been measured under such conditions(13).

It is recommended for these cases that reliable, site specific field measurements be made. The following mixing height model proposed by Benkley and Schulman(14) can then be used:

$$MIXH = \frac{0.185*U*k}{\ell n(Z/Z0)*f}$$

Where, U = Wind speed (m/s)
Z = Height U measured at (m)
Z0 = Surface roughness (m)
k = von Karman constant (0.35)
f = Coriolis parameter
= $1.45 \times 10^{-4} \cos\Theta$ (radians/sec)
Θ = 90° - site latitude

TABLE 1

Surface Roughness for Various Land Uses

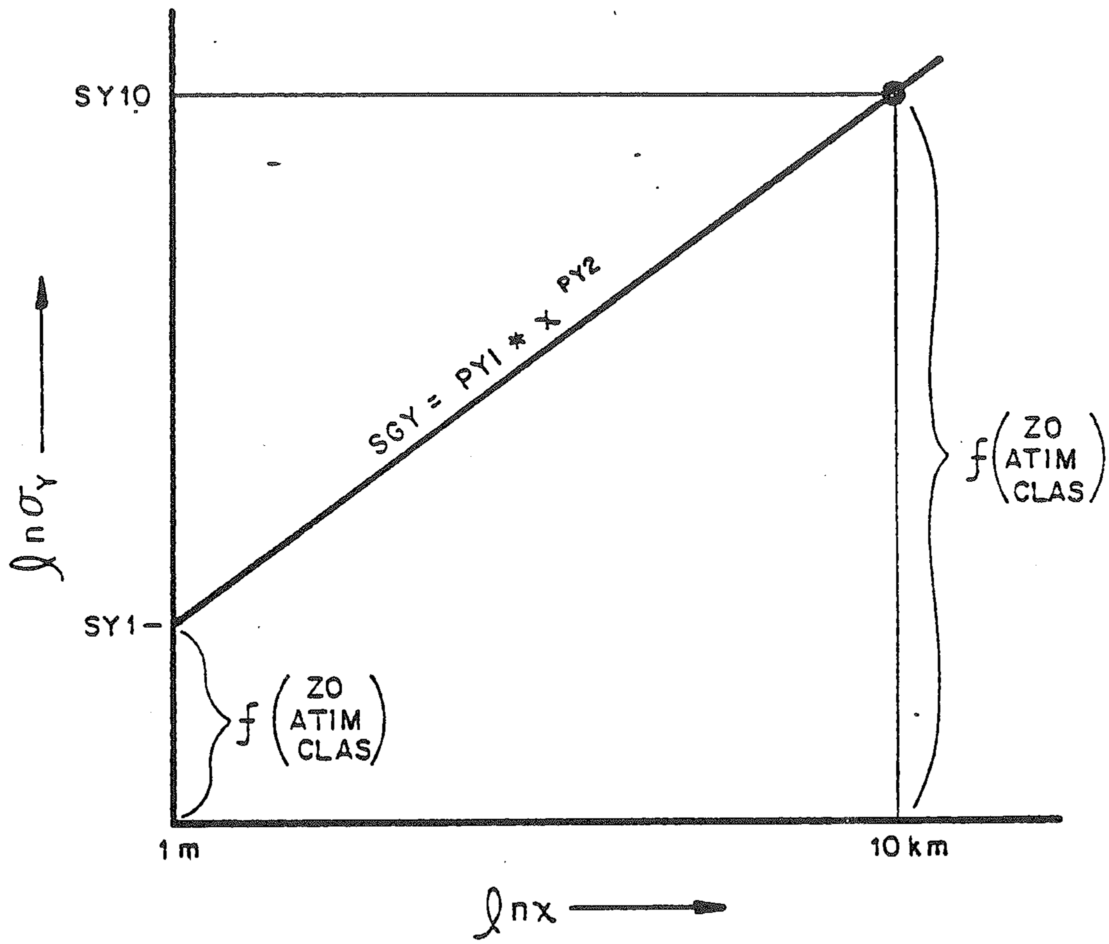
Type of Surface	ZO (cm)
Smooth mud flats	0.001
Tarmac (pavement)	0.002
Dry lake bed	0.003
Smooth desert	0.03
Grass (5-6 cm)	0.75
(4 cm)	0.14
Alfalfa (15.2 cm)	2.72
Grass (60-70 cm)	11.4
Wheat (60 cm)	22
Corn (220 cm)	74
Citrus orchard	198
Fir forest	283
City land-use	
Single family residential	108
Apartment residential	370
Office	175
Central Business District	321
Park	127

For nocturnal conditions with low mixing heights, wind speeds are likely to be less than 1 M/S. Extremely sensitive wind speed and direction instrumentation would be required for reliable results at such low wind speeds. In order to use CALINE3 for these conditions, measurements of the horizontal wind angle standard deviation will be needed. The model can then be modified to calculate horizontal dispersion parameters based on the methodology developed by Pasquill(15) or Draxler(16). The user is cautioned that the model has not been verified for wind speeds below 1 M/S, and that assumptions of negligible along-wind dispersion and steady state conditions are open to question at such low wind speeds.

Mixing height computations must be made for each element-receptor combination, and thus add appreciably to program run time. As will be seen in the sensitivity analysis, the mixing height must be extremely low to generate any significant response from the model. Therefore, it is recommended that the user bypass the mixing height computations for all but special nocturnal simulations. This is done by assigning a value of 1000 meters or greater to MIXH.

5.4 Horizontal Dispersion Curves

The horizontal dispersion curves used by CALINE3 are identical to those used by Turner(6) except for averaging time and surface roughness power law adjustments similar to those made for the vertical dispersion curves (see Fig. 12). The model makes no corrections to the initial horizontal dispersion near the roadway. The only roadway related alterations to the horizontal dispersion curves occur indirectly by defining the highway width as the width of the traveled way plus 3 meters on each side, and assuming uniform emissions throughout the element.



ZO = AERODYNAMIC ROUGHNESS
ATIM = AVERAGING TIME
CLAS = STABILITY CLASS
χ = PLUME CENTERLINE AXIS
σ_Y = HORIZONTAL DISPERSION PARAMETER
PY1 = exp (SY1)

HORIZONTAL DISPERSION CURVE-CALINE3

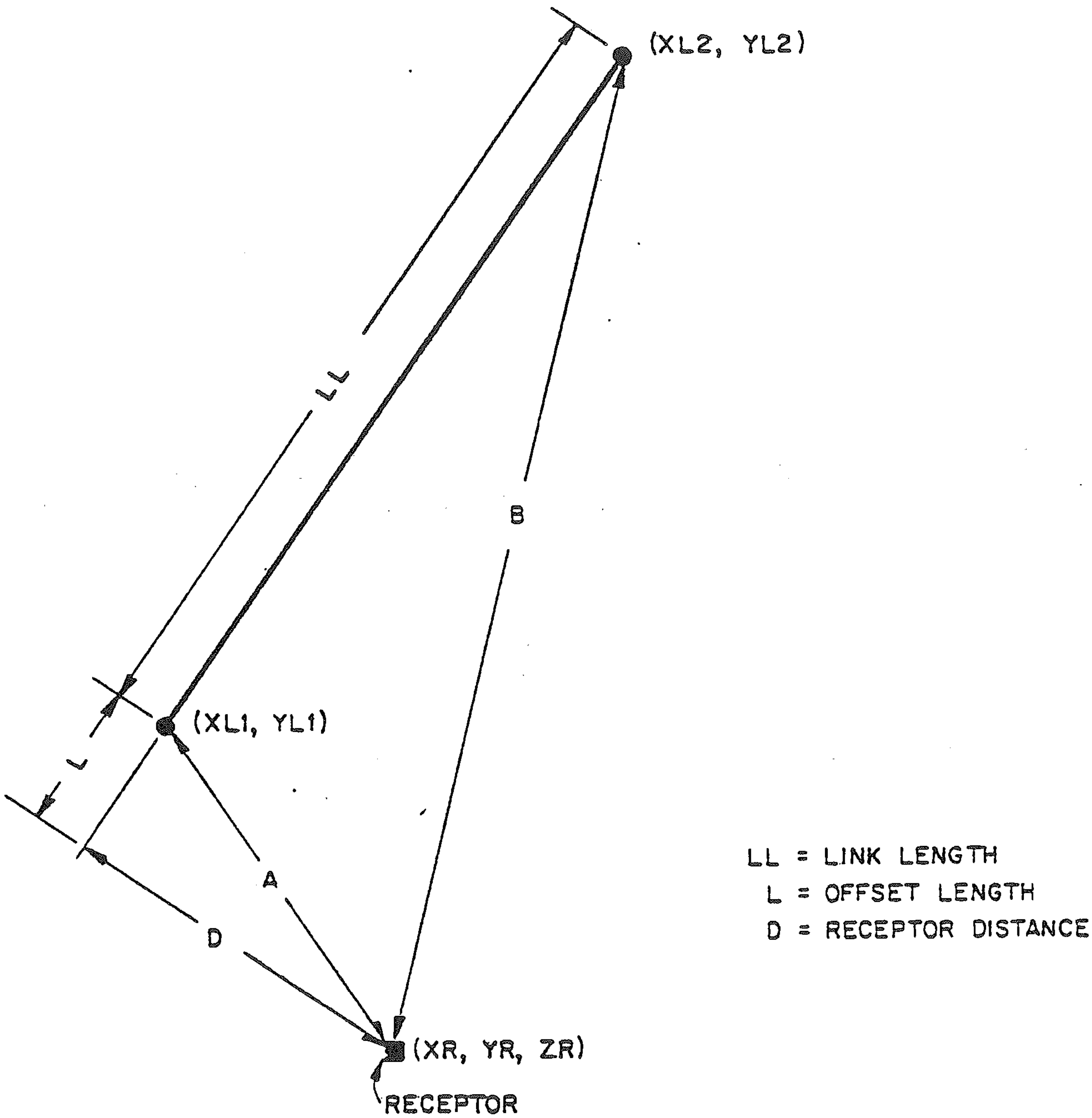
FIGURE 12

If field measurements of the horizontal wind angle standard deviation are available, site specific horizontal dispersion curves can be generated using the methodology developed by Pasquill(15) or Draxler(16). CALINE3 can then be easily reprogrammed to incorporate the modified curves. This approach is recommended whenever manpower and funding are available for site monitoring.

5.5 Site Geometry

CALINE3 permits the specification of up to 20 links and 20 receptors within an X-Y plane (not to be confused with the local x-y coordinate system associated with each element). A link is defined as a straight segment of roadway having a constant width, height, traffic volume, and vehicle emission factor. The location of the link is specified by its end point coordinates (see Fig. 13). The location of a receptor is specified in terms of X, Y, Z coordinates. Thus, CALINE3 can be used to model multiple sources and receptors, curved alignments, or roadway segments with varying emission factors. The wind angle (BRG) is given in terms of an azimuth bearing (0 to 360°). If the Y-axis is aligned with due north then wind angle inputs to the model will follow accepted meteorological convention (i.e. 90° equivalent to a wind directly from the east).

The program automatically sums the contributions from each link to each receptor. After this has been completed for all receptors, an ambient or background value (AMB) assigned by the user is added. Surface roughness is assumed to be reasonably uniform throughout the study area. The meteorological variables of atmospheric stability, wind speed, and wind



CALINE3 LINK GEOMETRY

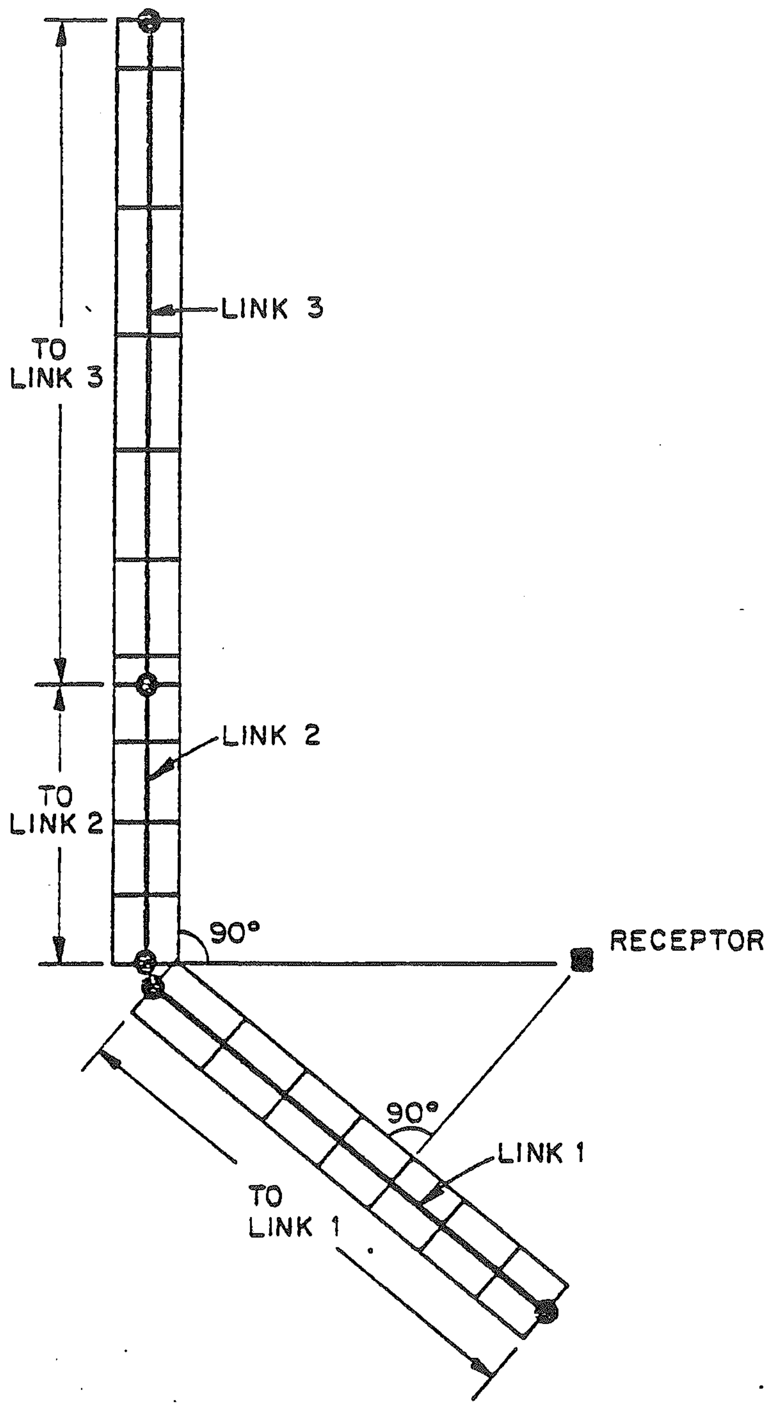
FIGURE 13

direction are also taken as constant over the study area. The user should keep this assumption of horizontal homogeneity in mind when assigning link lengths. Assigning a 10 kilometer link over a region with a terrain induced wind shift after the first 2 kilometers should be avoided. A 2 kilometer link would be more appropriate.

The elements for each link are constructed as a function of receptor location as described in Section 5.1 (see Fig. 14). This scheme assures that the finest element resolution within a link will occur at the point closest to the receptor. An imaginary displacement of the receptor in the direction of the wind is used by CALINE3 to determine whether the receptor is upwind or downwind from the link (see Fig. 15).

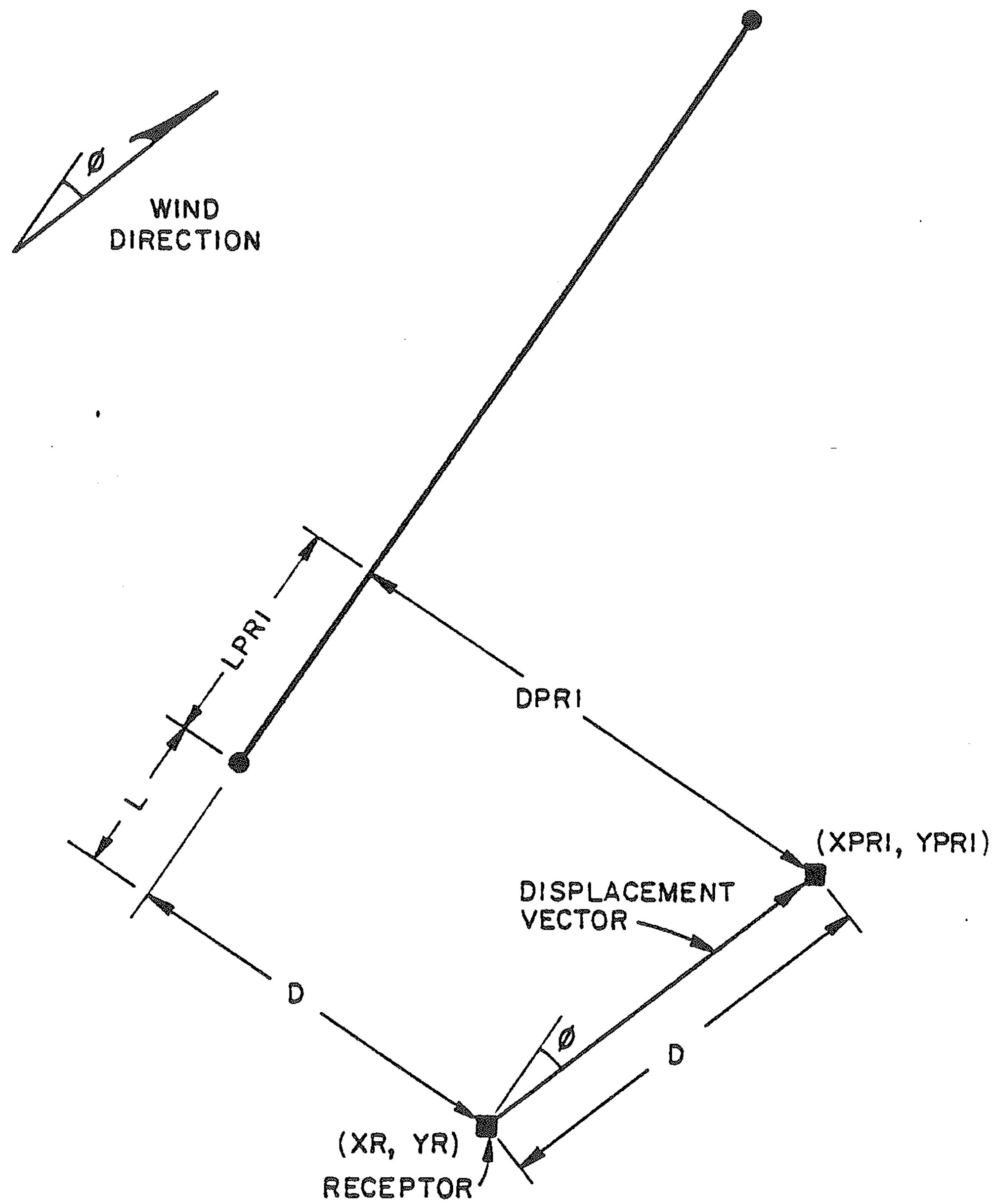
For each highway link specified, CALINE3 requires an input for highway width (W) and height (H). The width is defined as the width of the traveled way (traffic lanes only) plus 3 meters on each side. This 3 meter allowance accounts for the wake-induced horizontal plume dispersion behind a moving vehicle. The height is defined as the vertical distance above or below the local ground level or datum. CALINE3 should not be used in areas where the terrain in the vicinity of the highway is uneven enough to cause major spatial variability in the meteorology. Also, the model should not be used for links with values of H greater than 10 meters or less than -10 meters.

Elevated highway sections may be of either the fill or bridge type. For a bridge, air flows above and below the source in a relatively undisturbed manner. This sort of uniform flow with respect to height is an assumption of the Gaussian formulation. For bridge sections, H is specified as the height of



CALINE3 LINK– ELEMENT ASSIGNMENT

FIGURE 14



IF DPRI < D THEN D = −D

IF LPRI < L THEN $\begin{cases} UWL = -DWL \\ DWL = -UWL \end{cases}$

IMAGINARY DISPLACEMENT SCHEME USED BY CALINE3

FIGURE 15

the roadway above the surrounding terrain. For fill sections, however, the model automatically sets H to zero. This assumes that the air flow streamlines follow the terrain in an undisturbed manner. Given a 2:1 fill slope (effectively made more gradual as the air flow strikes the highway at shallower horizontal wind angles) and stable atmospheric conditions (suppressing turbulence induced by surface irregularities), this is a reasonable assumption to make(17).

For depressed sections greater than 1.5 meters deep, CALINE3 increases the residence time within the mixing zone by the following empirically derived factor based on Los Angeles data(3):

$$DSTR = 0.72* ABS(H)^{0.83}$$

This leads to a higher initial vertical dispersion parameter (SGZ1) at the edge of the highway. The increased residence time, characterized in the model as a lower average wind speed, yields extremely high concentrations within the mixing zone. The wind speed is linearly adjústed back to the ambient value at a distance of 3*H downwind from the edge of the mixing zone. By this point the effect of the higher value for SGZ1 dominates, yielding lower concentrations than an equivalent at-grade section.

For depressed sections, the model is patterned after the behavior observed at the Los Angeles depressed section site studied by Caltrans(3). Compared to equivalent at-grade and elevated sites, higher initial vertical dispersion was occurring simultaneously with higher mixing zone concentrations. It was concluded that channeling and eddying effects were effectively decreasing the rate of pollutant transport out of the depressed section mixing zone. Lower concentrations downwind of the highway were attributed to the more extensive vertical mixing occurring within the mixing zone. Consequently, the model yields higher values for concentrations within or close to the mixing zone, and somewhat lower values than would be obtained for an at-grade section for downwind receptors. Except for these adjustments, CALINE3 treats depressed sections computationally the same as at-grade sections.

It has been suggested that the model could be used for evaluating parking lot impacts. If the user wishes to run the model to simulate dispersion from a parking lot, it is recommended that SGZ1 be kept constant at 1 meter, and that the mixing zone width not be increased by 3 meters on each side as in the normal free flow situation. This is because the slow moving vehicles within a parking lot will impart much less initial dispersion to their exhaust gases.

5.6 Deposition and Settling Velocity

Deposition velocity (VD) is a measure of the rate at which a pollutant can be adsorbed or assimilated by a surface. It involves a molecular, not turbulent, diffusive process through the laminar sublayer covering the surface. Settling velocity (VS) is the rate at which a particle falls with respect to its immediate surroundings. It is an actual physical velocity of the particle in the downward direction. For most situations, a class of particles with an assigned settling velocity will also be assigned the same deposition velocity.

CALINE3 contains a method by which predicted concentrations may be adjusted for pollutant deposition and settling. This procedure, developed by Ermak(18), is fully compatible with the Gaussian formulation of CALINE3. It allows the model to include such factors as the settling rate of lead particulates near roadways(19) or dust transport from unpaved roads. A recent review paper by McMahon and Denison(20) on deposition parameters provides an excellent reference.

Most studies have indicated that CO deposition is negligible. In this case, both deposition and settling velocity adjustments can be easily bypassed in the model by assigning values of 0 to VD and VS.

6. SENSITIVITY ANALYSIS

A sensitivity analysis for CALINE3 is included in this report for the following reasons:

1. It provides a formalized means for checking the behavior of the model under a variety of conditions.

2. It allows the user to gauge the sensitivity of the model to each input parameter, thereby emphasizing those input parameters which need to be most accurately estimated.

3. It provides benchmark values against which users may check their copies of the model.

Because virtually all input parameters act independently within the model, interactions between two or more variables were presumed to be insignificant. Hence, perturbation of one variable at a time was considered sufficient for characterizing the overall sensitivity of the model.

The main series of sensitivity runs consist of CO concentration-wind angle (PHI) graphs. Each of these runs involves the perturbation of a discrete input variable. The runs were made for a single highway link, and were replicated for three distances from the highway centerline: 15, 30 and 60 meters. The perturbations were made from the following standard run:

TABLE 2

Standard Sensitivity Run

I. Site Variables

Wind Speed:	U = 1.0	(m/s)
Wind Direction:	BRG = variable	(deg)
Atmospheric Stability:	CLAS = 6	(F)
Mixing Height:	MIXH = 1000	(m)
Surface Roughness:	Z0 = 50	(cm)
Averaging Time:	ATIM = 60	(min)
Settling Velocity:	VS = 0	
Deposition Velocity:	VD = 0	
Ambient:	AMB = 0	

II. Link Variables

Traffic Volume:	VPH = 10,000	(vehicles/hr)
Emission Factor:	EF = 10	(gms/mi-vehicle)
Height:	H = 0	
Width:	W = 30	(m)
Link Coordinates:	X1 = 0	
	Y1 = 5000	(m)
	X2 = 0	
	Y2 = -5000	(m)

III. Receptor Locations

	XR = 15,30,60	(m)
	YR = 0	
	ZR = 0	

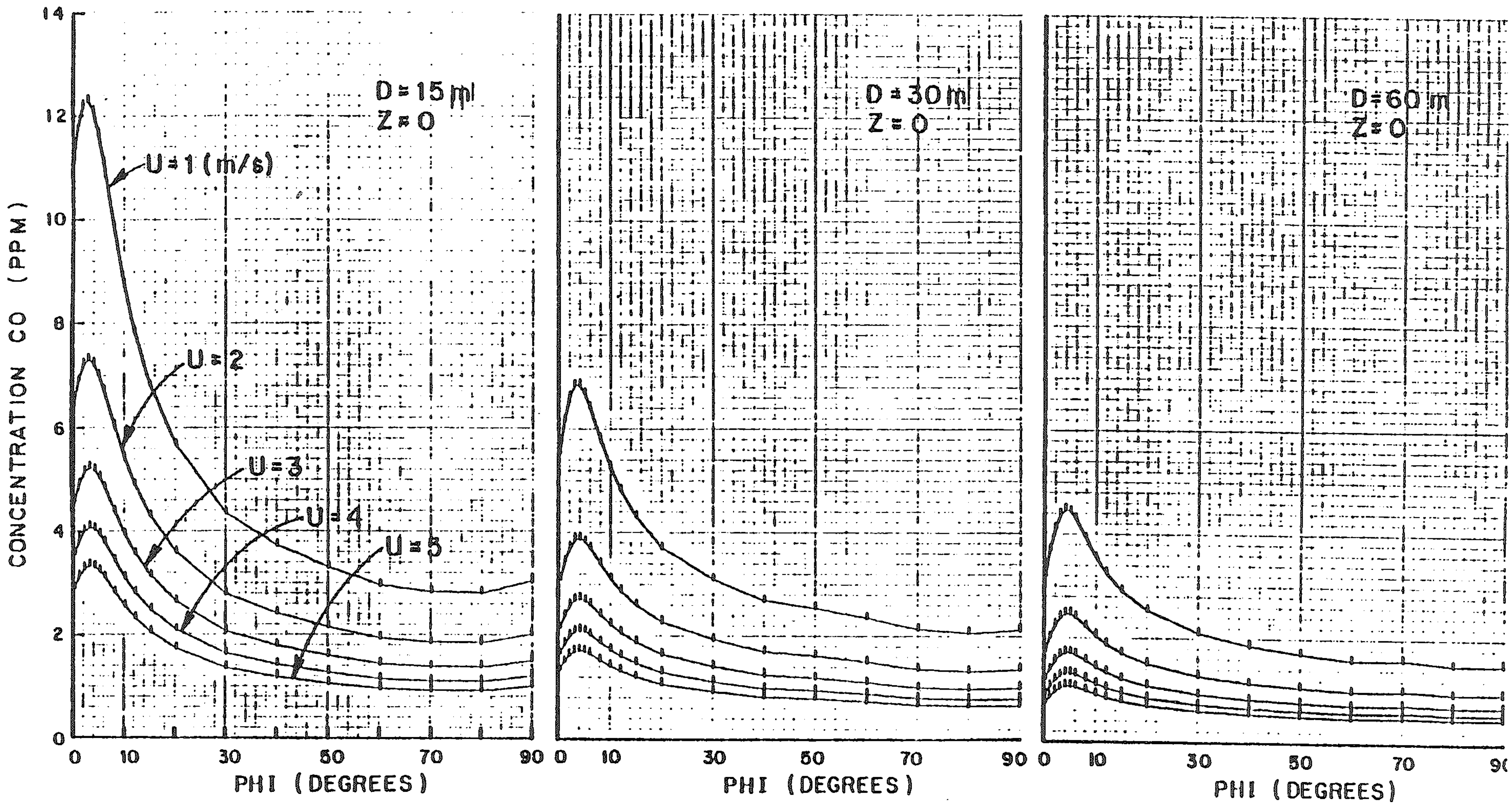
The actual computer results are shown as tic marks on the sensitivity graphs. No attempt was made to smooth the curves running through these computed values. A number of insignificant anomalies in the model behavior can be observed in the graphs. It is felt that these anomalies are due to the discrete nature of the element formulation. To smooth these out would require an increase in element and sub-element resolution, resulting in an increased computational time. This is not warranted by the magnitude of the anomalies.

6.1 Source Strength

The source strength used for CALINE3 is the product of the vehicle emission factor and traffic volume. It is directly proportional to the predicted concentration. Hence, a two-fold increase in either the vehicle emission factor or the traffic volume will result in a doubling of the predicted concentration. Because of this simple relationship, no sensitivity analysis was run on source strength.

6.2 Wind Speed (see Fig. 16)

Wind speed enters CALINE3 computations in two ways. In the Gaussian equation, the predicted concentration is inversely proportional to the wind speed. However, the wind speed also determines the time of residence within the mixing zone. This is related to the value of the vertical dispersion parameter at the edge of the roadway.



CALINE3 SENSITIVITY ANALYSIS - VARIABLE: WIND SPEED (U)

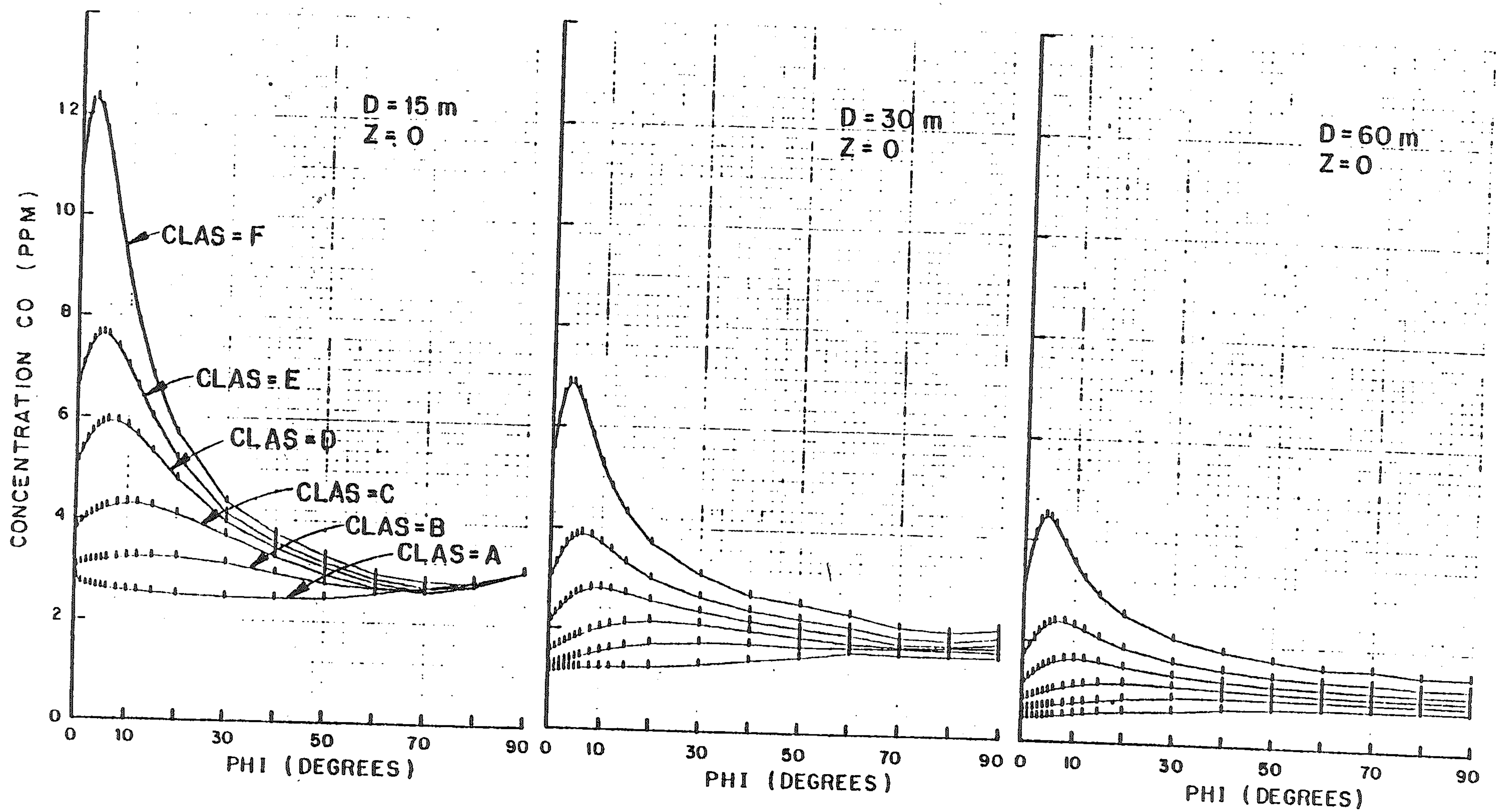
FIGURE 16

The sensitivity analysis was run for wind speeds of 1 to 5 meters per second. Despite the slightly offsetting effect of higher initial vertical dispersion at lower wind speeds, predicted concentrations are higher for low wind speeds in all cases. The relative sensitivity of the model results to wind speed does increase at greater distances from the roadway. Thus, the impact of high initial vertical dispersion lessens with distance from the roadway. Also, by comparing concentration ratios it can be seen that crosswind predictions are much more sensitive to the initial vertical dispersion algorithm than are parallel wind predictions. Both these observations are compatible with the thesis that at greater distances the effect of initial traffic induced vertical mixing becomes less significant. This leads to the conclusion that accurate characterization of initial vertical mixing as a function of residence time, and perhaps also vehicle speed and traffic volume, is more important for intersection modeling, where the significant contributing elements are near the receptor, than for freeway modeling.

For all wind speeds, the maximum concentrations occur for near parallel wind conditions. These maximums become less pronounced at higher wind speeds, however. The location of the maximums appears to be relatively insensitive to wind speed and receptor distance.

6.3 Atmospheric Stability (see Fig. 17)

The critical wind angle at which maximum concentration occurs is much more sensitive to atmospheric stability class than to wind speed. In fact, for the most unstable class (A), the maximum is observed to occur under crosswind conditions.



CALINE3 SENSITIVITY ANALYSIS – VARIABLE: STABILITY CLASS (CLAS)

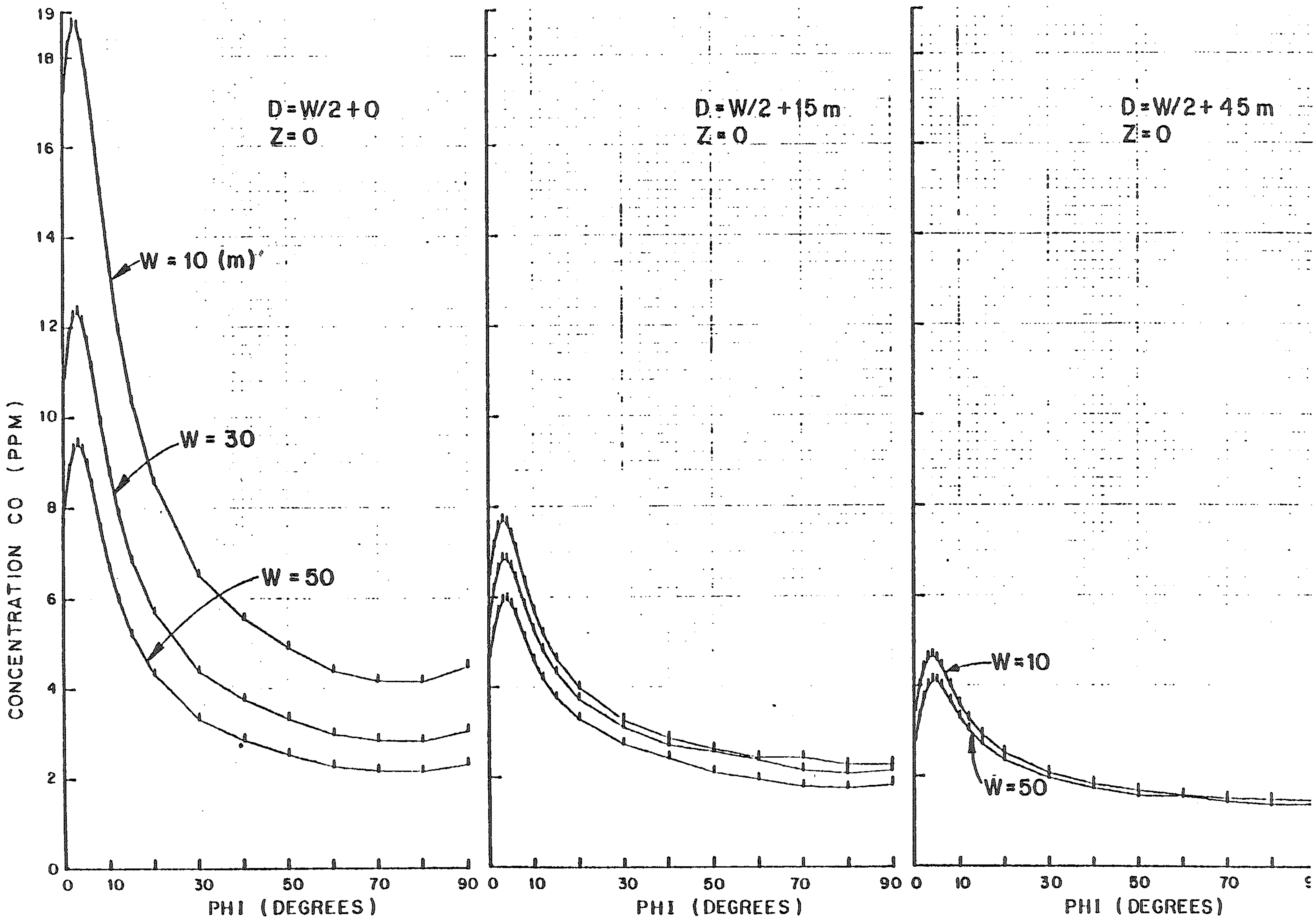
FIGURE 17

At the edge of the highway (D = 15 meters) the predicted concentration is totally independent of stability class under crosswind conditions. This is because the vertical dispersion at this point is controlled totally by the residence time over the mixing zone, and because concentrations for a semi-infinite link under crosswind conditions are independent of horizontal dispersion. At greater distances, the effects of atmospheric stability begin to appear. The shifting of the critical angle from near parallel to crosswind conditions can be attributed to the increases in vertical and horizontal dispersion that occur under more unstable atmospheric conditions. These increases make the contributions from distant elements less and less important as atmospheric instability increases.

6.4 Highway Width (see Fig. 18)

By widening the highway, the residence time over the mixing zone and the initial horizontal distribution of the source are both increased. Thus, both vertical and horizontal dispersion are enhanced. Given a constant source strength, and a receptor distance referenced from the downwind edge of the roadway, the model consistently predicts lower concentrations for greater highway widths. This effect is most apparent for receptors near the roadway edge. The sensitivity of the model to highway width is relatively independent of the wind angle. As with wind speed, the value of the critical angle for maximum concentration is relatively insensitive to highway width.

If receptor distances for this analysis were not adjusted for the varying widths (i.e., D = W/2 + constant), the effects of enhanced dispersion over the mixing zone would be more than offset by the increasing closeness of the mixing zone to the receptor.



CALINE3 SENSITIVITY ANALYSIS – VARIABLE: HIGHWAY WIDTH (W)

FIGURE 18

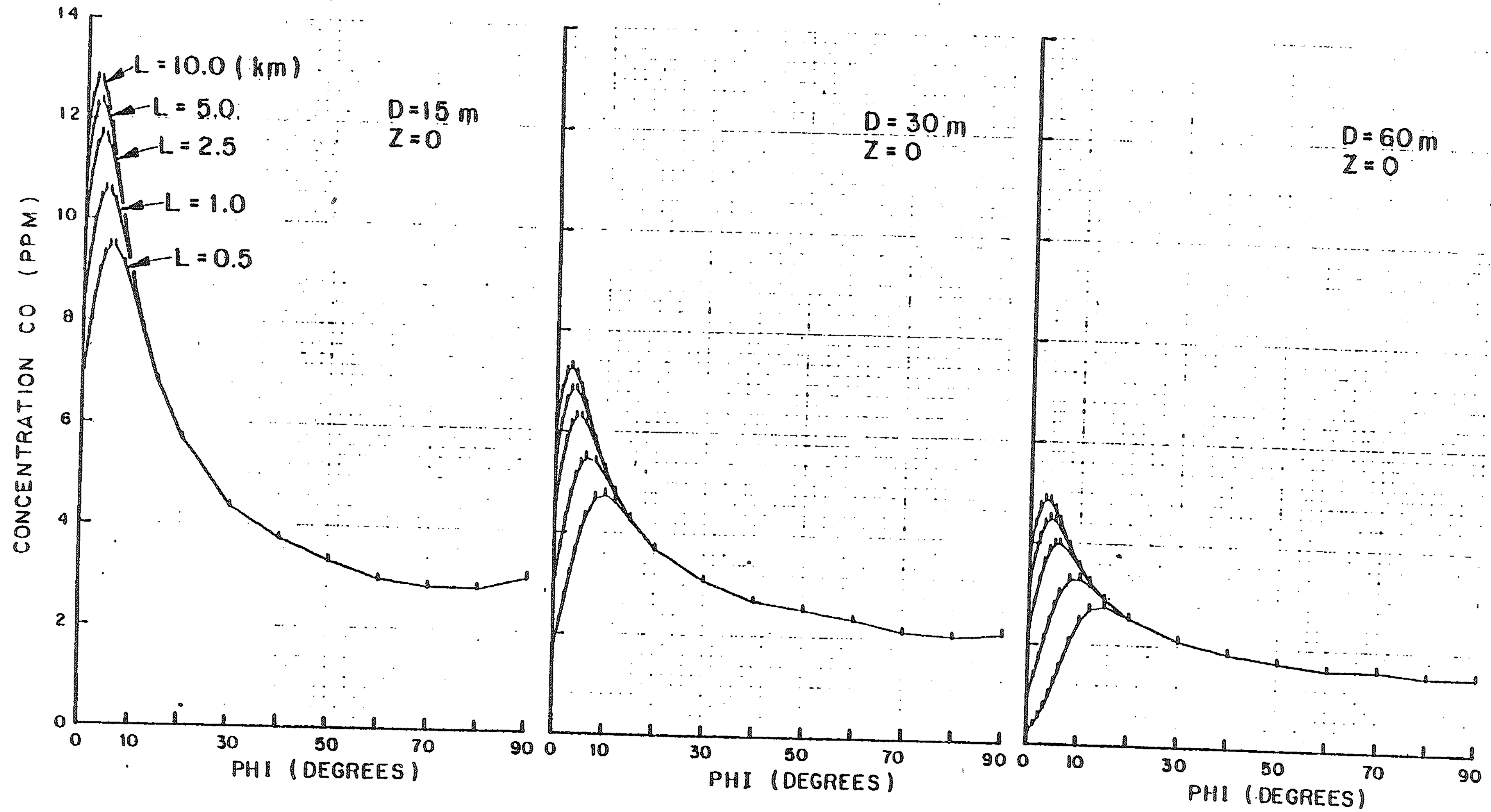
6.5 Highway Length (see Fig. 19)

The pronounced peak concentrations for nearly parallel winds which are characteristic of CALINE3 are the result of the transport of pollutants from distant highway elements under stable atmospheric conditions. By reducing the highway length being modeled, a substantial reduction in the near-parallel wind peak concentrations occurs. Reduction of the highway length has virtually no effect on oblique and crosswind predictions except in very extreme cases. Location of the critical wind angle for maximum concentration is extremely sensitive to highway length, especially at larger receptor distances. Note that CALINE3 should not be used for highway lengths greater than 10 kilometers. Also note that the highway length being quoted in the sensitivity analysis is actually equal to one-half the link length (i.e. L = 5 kilometers is equivalent to Y1 = 5000 meters, Y2 = -5000 meters).

6.6 Surface Roughness (see Fig. 20)

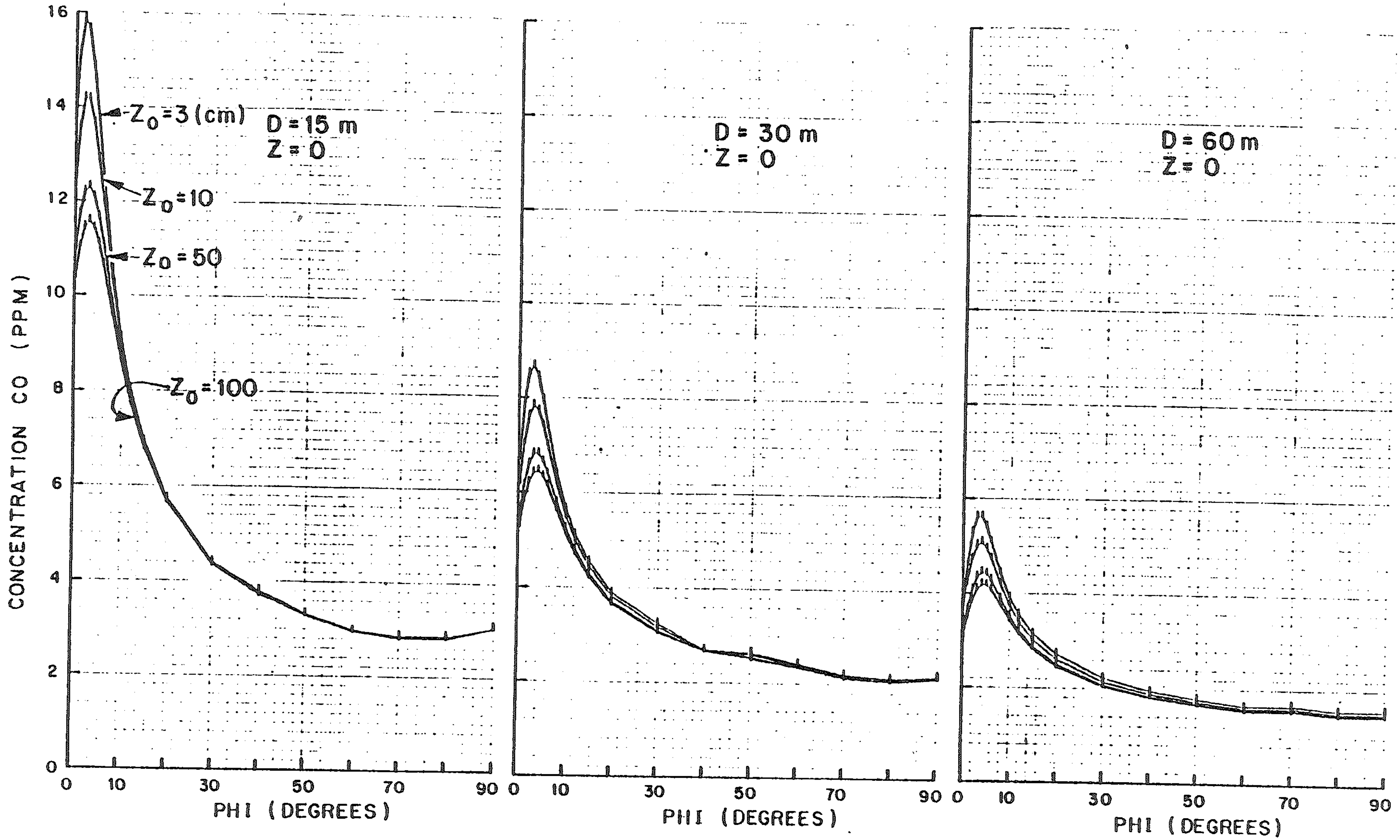
Mechanical turbulence is generated by air movement over surface roughness elements. An increase in the surface roughness increases the amount of mechanical turbulence generated. This enhances both vertical and horizontal dispersion of pollutants in the surface layer, especially for near ground releases.

CALINE3 is relatively sensitive to surface roughness for near parallel wind conditions. For crosswind conditions, predicted concentrations are dominated by the initial vertical mixing within the mixing zone which is independent of surface roughness. However, at greater receptor distances, there is a slight sensitivity in the model to surface roughness even



CALINE3 SENSITIVITY ANALYSIS – VARIABLE: HIGHWAY LENGTH (L)

FIGURE 19



CALINE3 SENSITIVITY ANALYSIS – VARIABLE: ROUGHNESS (ZO)

FIGURE 20

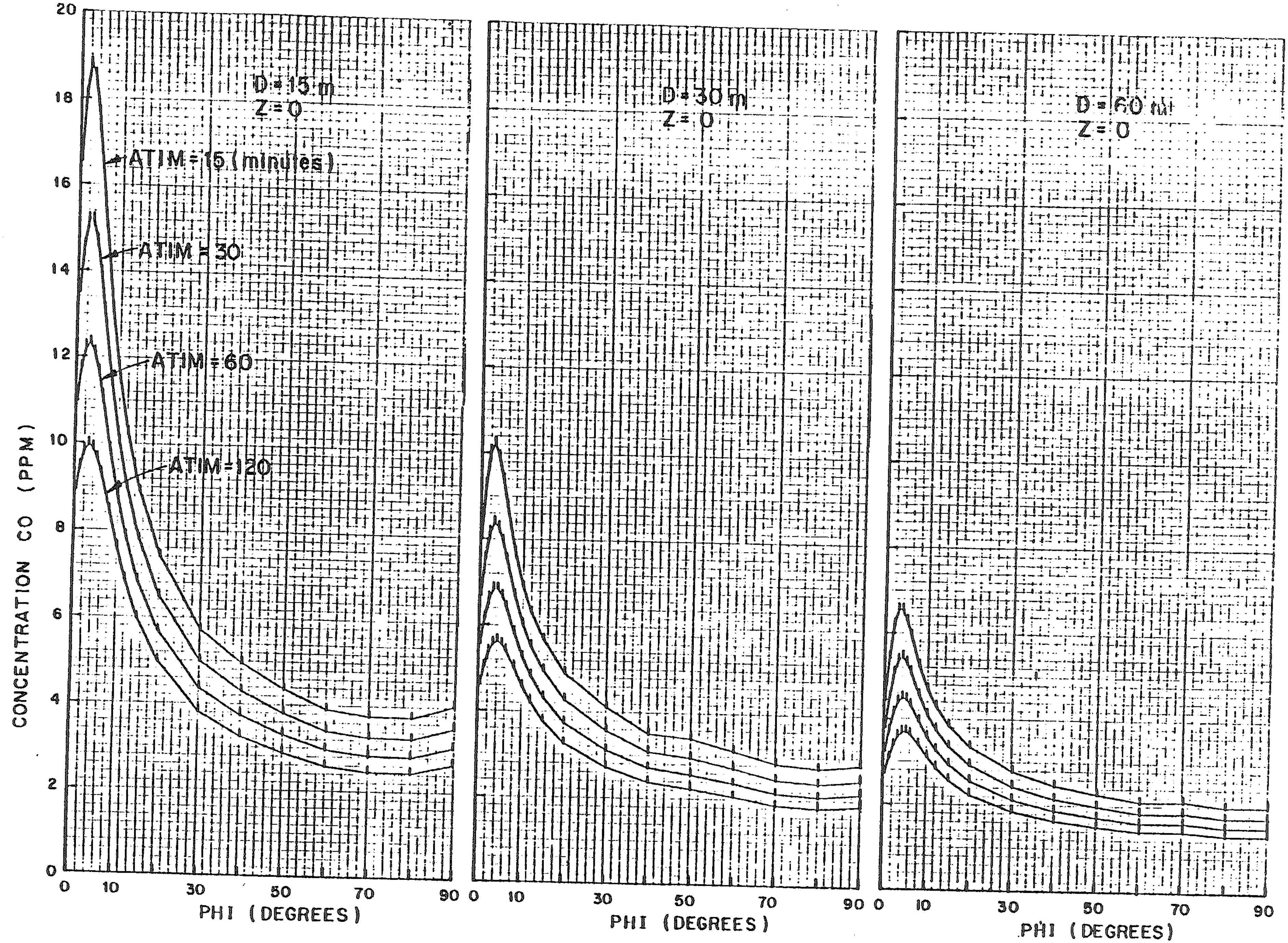
under crosswind conditions. The value of the critical wind angle for maximum concentration is virtually independent of surface roughness.

6.7 Averaging Time (see Fig. 21)

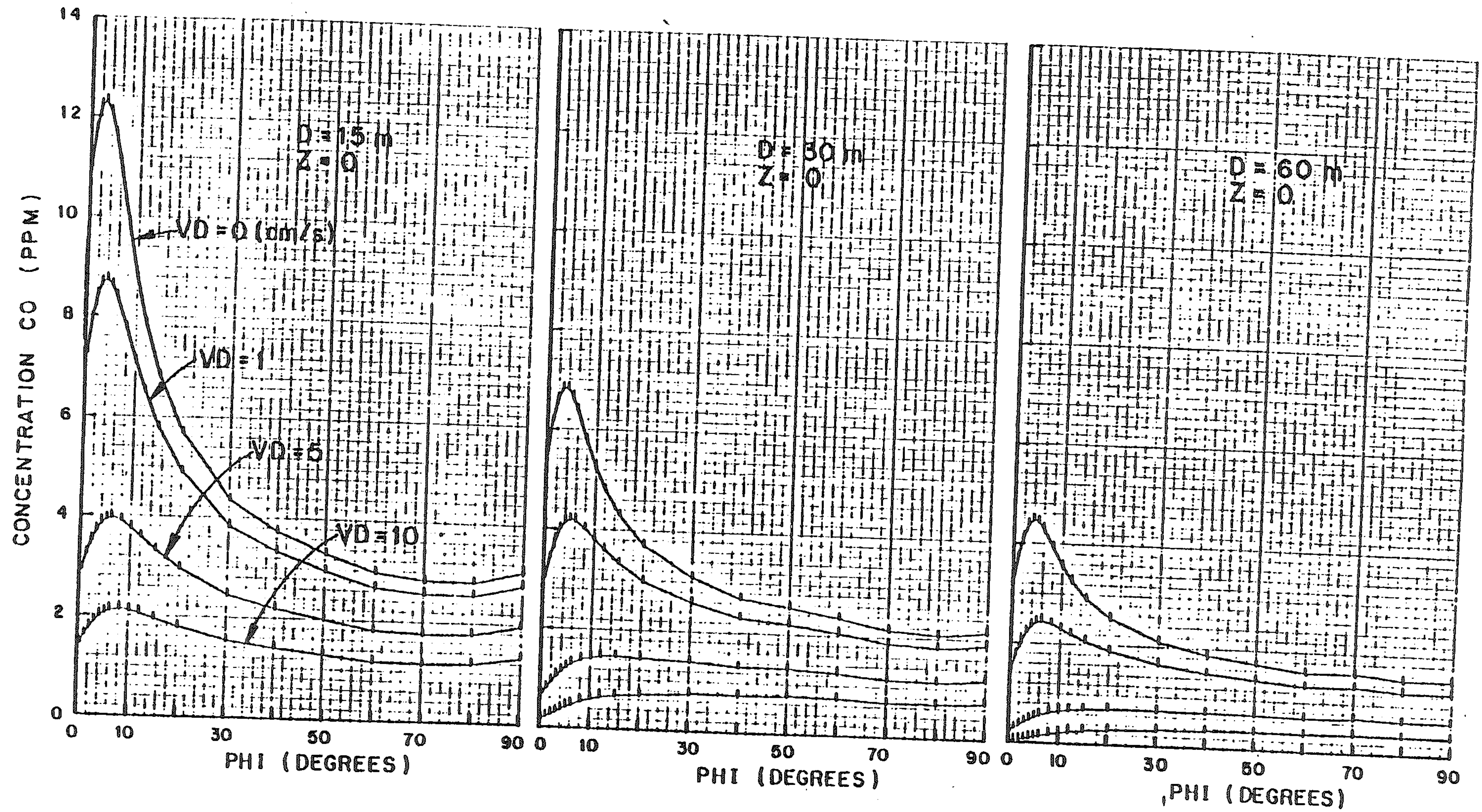
The number of statistically independent turbulent fluctuations occurring at a point in a turbulent medium is directly related to the averaging time (the time span over which observations have been made). For short averaging times, a less variable family of turbulent fluctuations is to be expected. Hence, pollutant dispersion is lessened. For the range of averaging times shown, 5 to 120 minutes, CALINE3 is extremely sensitive, both for parallel and crosswind conditions. The model has been verified only at 30 minute and 60 minute averaging times. Location of the critical wind angle for maximum concentration is not related to averaging time.

6.8 Deposition Velocity (see Fig. 22)

A significant deposition velocity tends to lessen the impact of distant elements on receptor concentration (the longer the time of travel, the more material deposited). For CALINE3, an increasing deposition velocity tends to flatten the near parallel wind concentration peaks. At distant receptors under certain conditions, maximum concentrations can occur during crosswind conditions, even under stable atmospheric conditions. While deposition velocity has its greatest effect on near parallel wind predictions, it also significantly effects crosswind predictions.



CALINE3 SENSITIVITY ANALYSIS - VARIABLE: AVERAGING TIME (ATIM)



CALINE3 SENSITIVITY ANALYSIS — VARIABLE: DEPOSITION VELOCITY (VD)

FIGURE 22

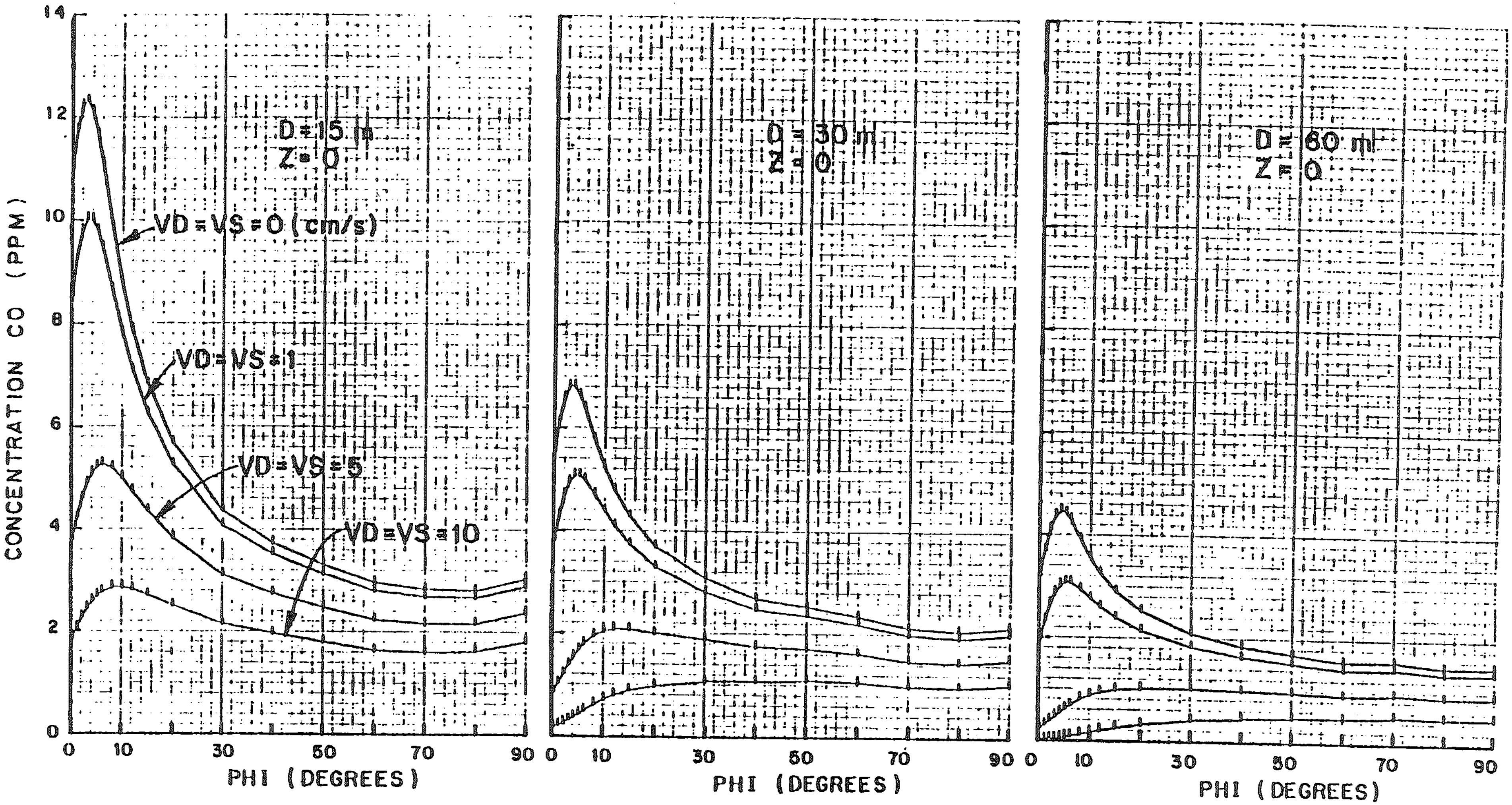
6.9 Settling Velocity (see Fig. 23)

While deposition velocity controls the amount of material leaving the air to be deposited on the ground, settling velocity can actually inhibit the vertical dispersion of a pollutant. Increased settling velocity decreases the importance of distant elements. Thus, the same type of model results occur with the settling velocity as with deposition velocity. However, somewhat higher concentrations are observed when settling velocities are set equal to the deposition velocities. This is due to the inhibition of vertical pollutant dispersion coupled with the fact that the sensitivity runs were made for ground level receptors.

Note that the deposition velocity is assumed to be equal to the settling velocity. Presumably the settling velocity of a particle will be identical whether in a turbulent regime or within the laminar sublayer. If one were to assign a settling velocity and set the deposition velocity equal to zero, extremely high ground concentrations would be predicted. This would not be a realistic use of the model.

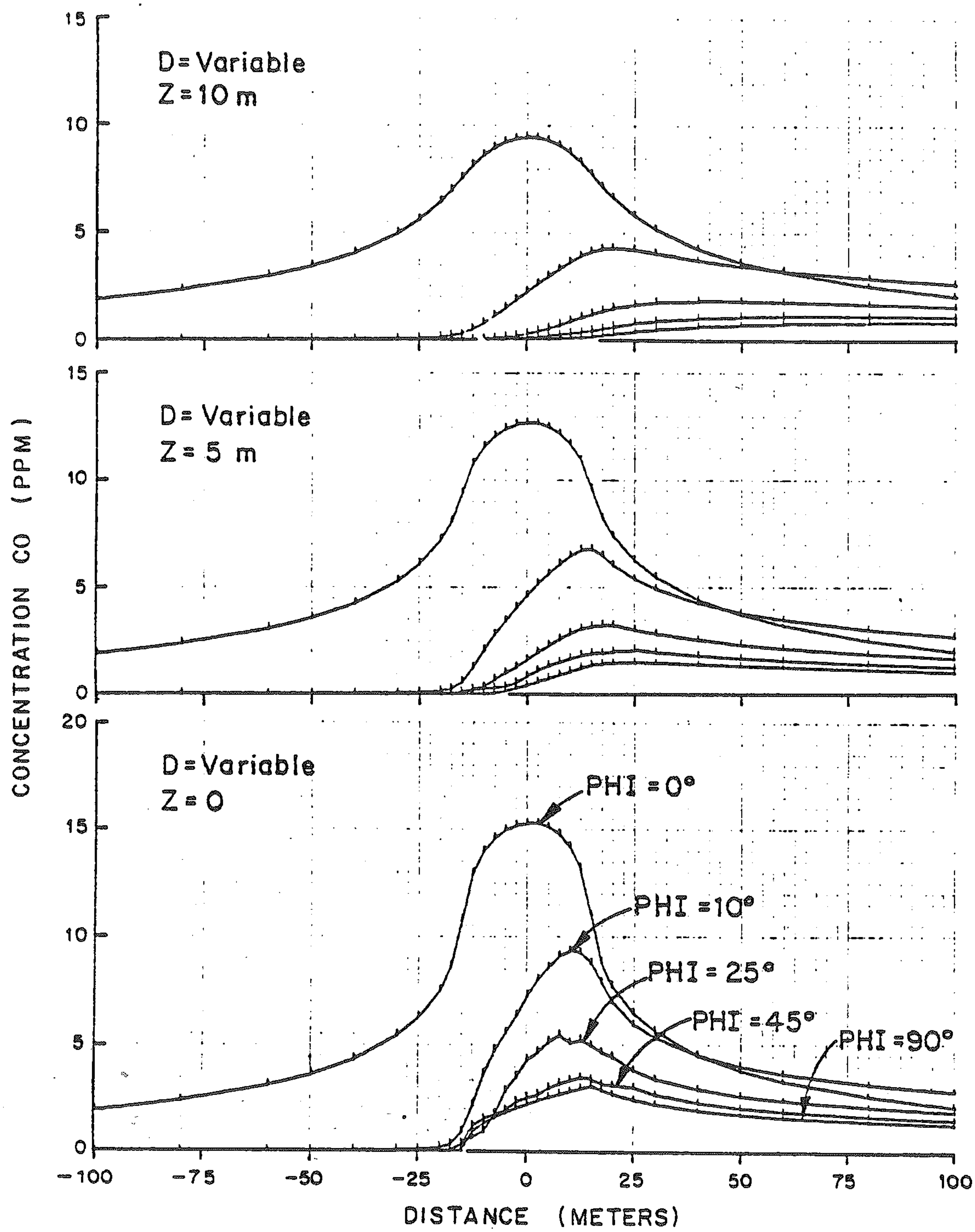
6.10 Wind Angle (see Fig. 24)

CALINE3 can predict pollutant concentrations for receptors both upwind and downwind of the highway. It can also make predictions for receptors located within the mixing zone. The model has been verified for downwind distances up to approximately 150 meters. Verification of the model for upwind receptors was not as successful, however. The probable reasons for this can be seen in the receptor distance sensitivity run. Predicted concentrations for upwind receptors



CALINE3 SENSITIVITY ANALYSIS — VARIABLE: DEPOSITION & SETTLING VELOCITY (VD, VS)

FIGURE 23



CALINE3 SENSITIVITY ANALYSIS — VARIABLE: WIND ANGLE (PHI)

FIGURE 24

are extremely sensitive to wind angle. In most cases, however, a poor verification result for an upwind receptor is insignificant (i.e. the difference between a measured value of .5 ppm CO and a predicted value of .1).

Predicted concentrations near and within the mixing zone are somewhat sensitive to receptor height. However, for distant receptors there is little noticeable difference as a function of receptor height. This implies a fairly uniform distribution of the pollutants within the first 10 meters of the surface layer for distant receptors (say D = 100 meters).

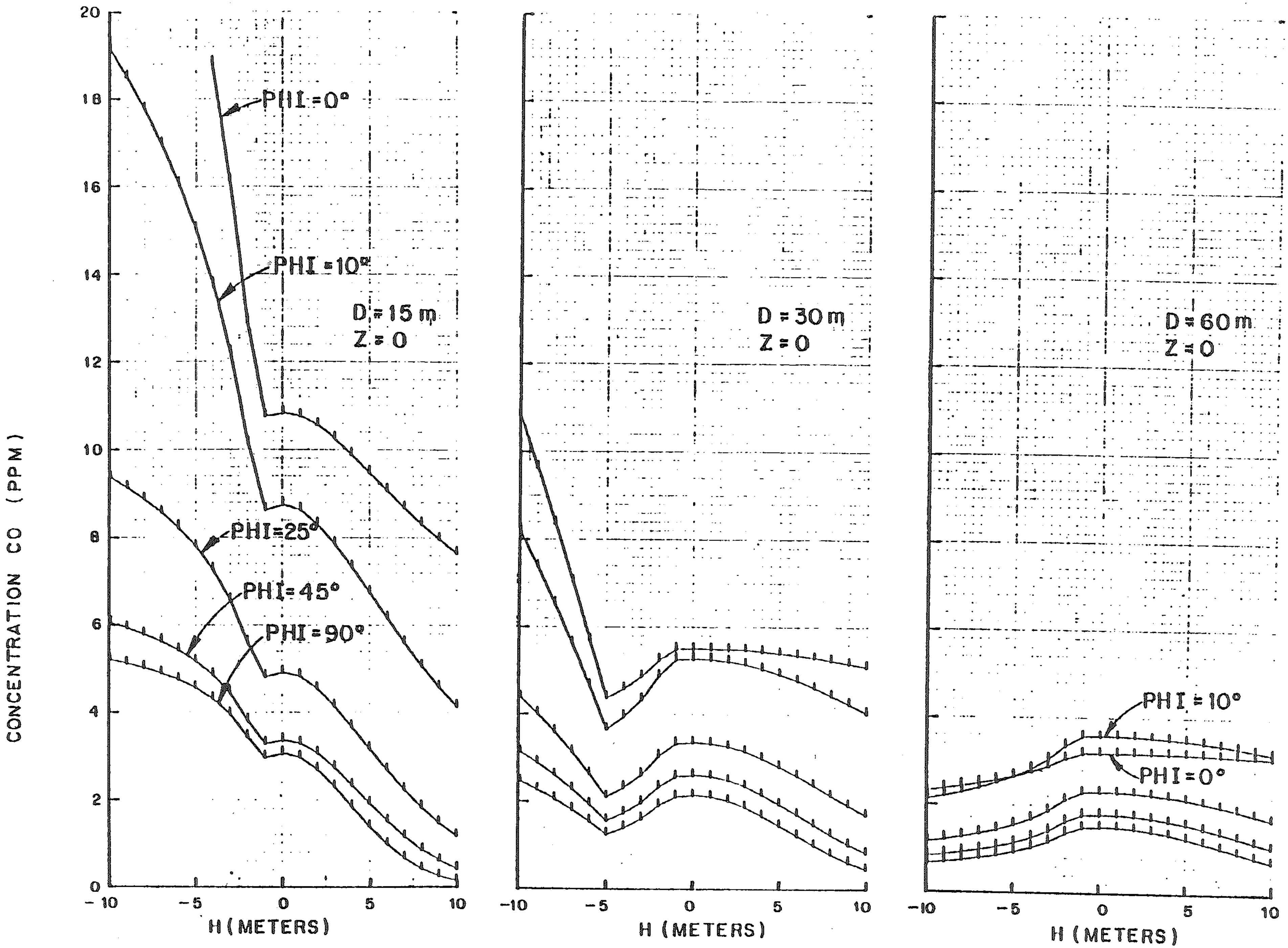
Note that peak concentrations for pure parallel winds occur along the centerline of the roadway. The previous graphs showing peak concentrations occurring usually in the 3° to 4° range were for receptors at the edge of the roadway (D = 15 meters). For oblique winds, an expected decrease in predicted concentrations occurs across the roadway. The crossover point for wind angle curves of 0° and 10° occurs further from the roadway for greater receptor heights. Therefore, one would expect the critical wind angle of maximum predicted concentration to shift inward toward the pure parallel wind condition for increased receptor heights. This is due to the lowering of contributions from the closest elements as the receptor height is increased. These close elements, with still tightly directed plumes, are the ones that cause peak concentrations to occur at wind angles of 3 to 4° (under standard run conditions) for ground level receptors at the roadway edge.

6.11 Source Height (see Fig. 25)

The model response to changes in source height is quite complex, though based on simple underlying assumptions. If the highway is elevated as a bridge above a receptor, predicted concentrations generally decrease. This decrease is much more significant for crosswind conditions than for parallel wind conditions. For crosswind conditions, significant contributions for receptor concentrations come from nearby elements so that the effect of source elevation is important. Under parallel wind conditions, this effect is less significant because of the larger distances over which pollutants must travel.

For depressed sections, CALINE3 predicts high concentrations for receptors located within and near the highway. This area for depressed sections is defined as the highway width plus a distance equal to three times the absolute value of the source height. The algorithms used for predicting concentrations near depressed sections were empirically derived from data collected at a depressed section site along the Santa Monica Freeway in Los Angeles. The data showed particularly higher than normal concentrations within the depressed section and lower concentrations at receptors outside of the depressed section. As can be seen in the sensitivity run, this is exactly how CALINE3 responds to negative source height.

The increased concentrations predicted within and near the depressed section become more pronounced as the wind angle approaches parallel wind conditions. For the distant receptor, the crossover between the PHI = 0° and PHI = 10° curves is simply the result of the trade off between close and distant contributing elements. For a receptor located 60 meters downwind from the roadway centerline, short to medium distance



CALINE3 SENSITIVITY ANALYSIS — VARIABLE: SOURCE HEIGHT (H)

FIGURE 25

elements are strong contributors and lead to a higher predicted concentration for the 10° angle than the 0° angle. However, for deeper depressed sections, longer residence time creates more initial mixing thereby lessening the impact of these close to medium distance elements.

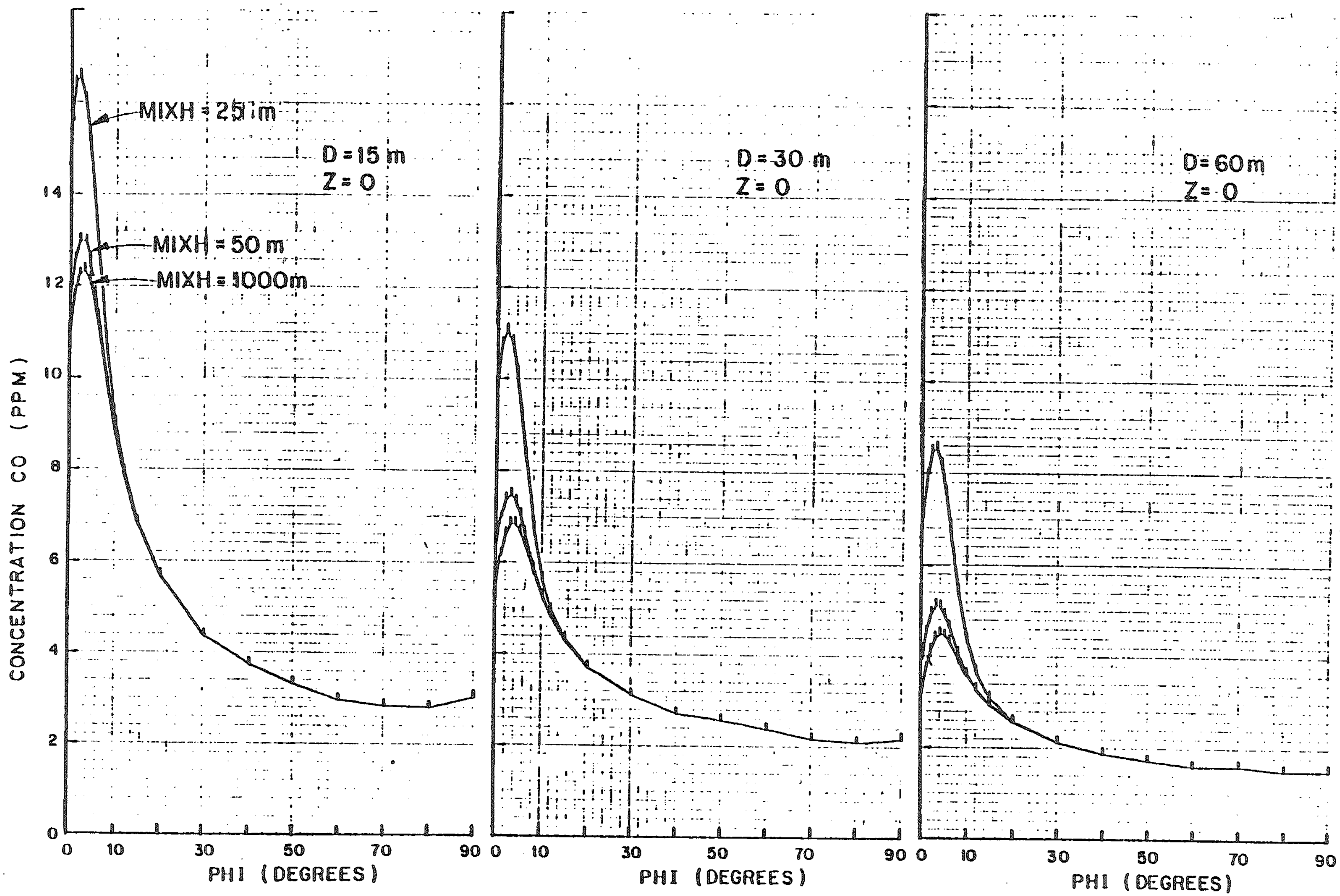
6.12 Mixing Height (see Fig. 26)

Model sensitivity to mixing height (MIXH) is significant only for extremely low values occurring under parallel wind conditions. This is essentially because of the small amount of vertical dispersion that can take place under stable conditions within the limits of the microscale region. In fact, the model response for MIXH=100 meters was so close to MIXH=1000 meters that no difference could have been seen on the sensitivity graphs.

Under unstable atmospheric conditions, model sensitivity to MIXH would increase. However, low level inversions are not really compatible with unstable conditions. It should be remembered that the mixing height algorithm is primarily meant for study of special case nocturnal inversions, and may be bypassed by assigning a value of 1000 meters or greater to MIXH.

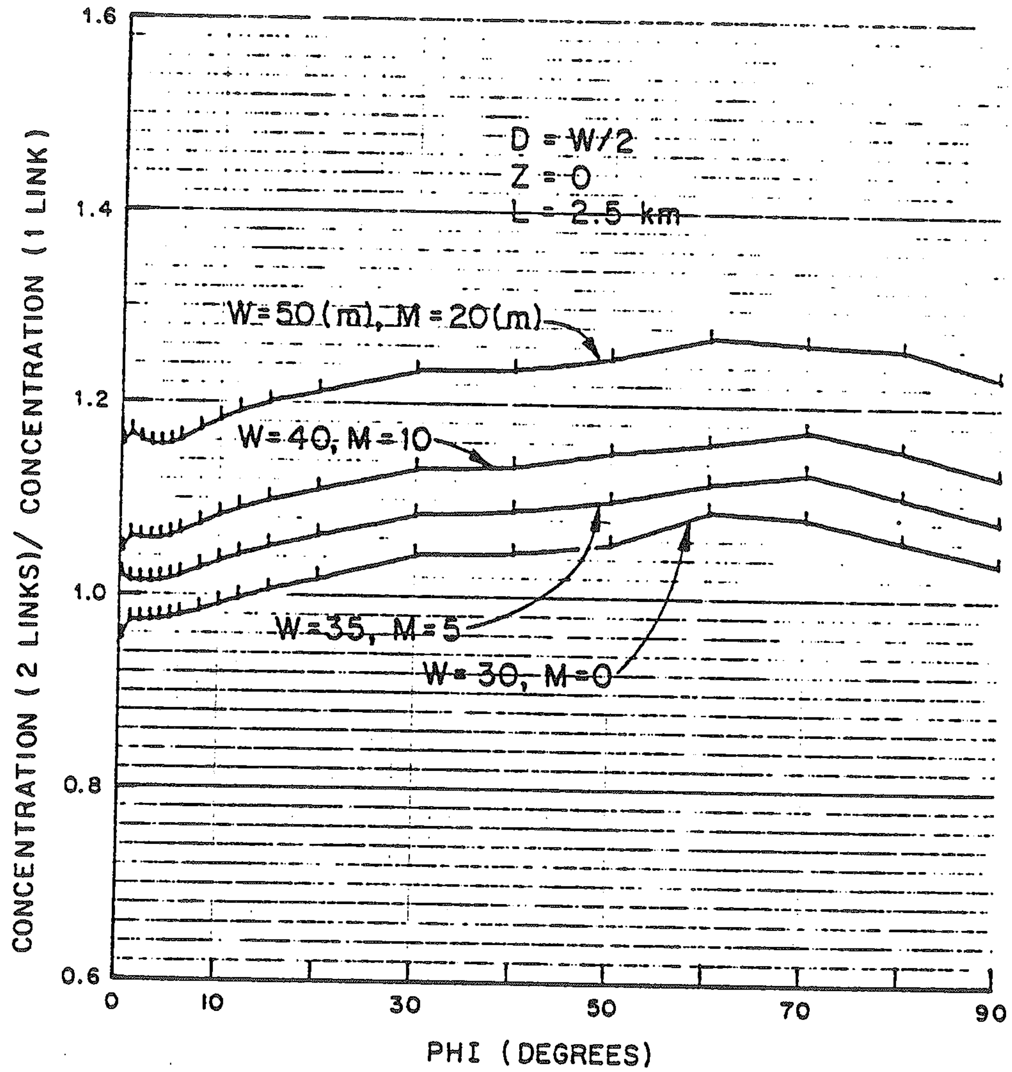
6.13 Median Width (see Fig. 27)

Because of the link capabilities of CALINE3, it is no longer necessary to incorporate medians as part of the mixing zone. A divided roadway may be modeled as either two separate links or a single link with the median incorporated in the highway



CALINE3 SENSITIVITY ANALYSIS – VARIABLE: MIXING HEIGHT (MIXH)

FIGURE 26



CALINE3 SENSITIVITY ANALYSIS – HIGHWAY WIDTH (W), MEDIAN WIDTH (M)

FIGURE 27

width specification (this assumes identical link specifications for both directions of flow). For cases where there is a significant median involved, the two link computation gives slightly higher predicted concentrations over the single link model. This holds true for virtually all wind angles, but tends to be slightly more pronounced for crosswind conditions.

As a guideline to the user, single link computations should incorporate medians no greater than 10 meters in width. This figure is justified since verification of the CALINE3 model on the GM data base (median width = 11.8 meters) was performed as a single link computation. In the GM data base, however, traffic volume and emission factors were identical in both directions of flow. Any application in which there is a significant difference between these parameters should be modeled as two separate links.

7. MODEL VERIFICATION

The CALINE3 model was verified using data obtained from three separate sources: The General Motors Sulfate Experiment(4), a Stanford Research Institute Monitoring Study(10), and the Caltrans Los Angeles Study(3). As a standard of comparison, CALINE2 results were also included in the verification study.

Two methods of comparison between predicted and measured concentrations were used in this analysis. The first consisted of an overall plot of predicted versus measured concentrations regardless of receptor location and wind angle. These overall plots give a general picture of the accuracy of the model. The degree to which the results follow a 45° line and the amount of scatter around that line are the important descriptors of model accuracy and precision, respectively.

Normally, for model calibration studies the measured values are made the dependent (vertical axis) variable so that the resulting calibration curve can be used to adjust model predictions to measured results. For a verification analysis, however, the model predictions are made the dependent variable so that the regression analysis is directed at the model residuals (in this case, a residual is defined as the difference between the model result and the expected model result).

The second method involved plotting of a comparison factor, F, against the wind angle, PHI, for stable atmospheric conditions. This was used to provide a more detailed performance evaluation of model accuracy under stable, parallel wind conditions. The comparison factor was computed as follows:

$$F = 100 * (P-M)/(P+M)$$

Where, P = Predicted
M = Measured

This factor has the quality of responding similarly for both positive and negative cases of predicted minus measured, and has fixed upper and lower limits. For these reasons it was chosen over the simpler factor of P/M. Conversion to P/M results can be made using the following formula:

$$P/M = (100+F)/(100-F)$$

In studying the model verification results, one must realize that the variability in the results is not only a function of the model's accuracy, but also the errors inherent in field observations (especially for low concentrations) and, for two of the data bases, the inaccuracies of emission factor modeling.

7.1 General Motors Data Base

The General Motors (GM) Sulfate Experiment was conducted at the GM Milford, Michigan proving grounds straightaway track during the month of October 1975. The track is 5 kilometers long and is surrounded by lightly wooded, rolling hills. Three hundred and fifty-three cars, including 8 vehicles emitting tracer gas, were driven at constant speeds of 80 km/hr around the track. This simulated a traffic flow of 5,462 vehicles per hour along a four lane freeway with a median width of approximately 12 meters.

Monitoring probes were stationed at 5 distances up to 100 meters downwind from the edge of the roadway. The closest three locations were equipped with tower mounted sampling probes at elevations of .5, 3.5 and 9.5 meters above the ground. Two additional and more distant probes were located at an elevation of .5 meter.

The use of sulfur hexafluoride (SF_6) as a tracer gas in 8 of the vehicles eliminated interference from background pollutant levels. Since SF_6 is an extremely inert gas, its downwind concentrations could be predicted by CALINE2 and CALINE3 without violating the steady state assumptions of the Gaussian formulation.

The following values of input parameters were used to run the models:

TABLE 3

GM Input Parameters

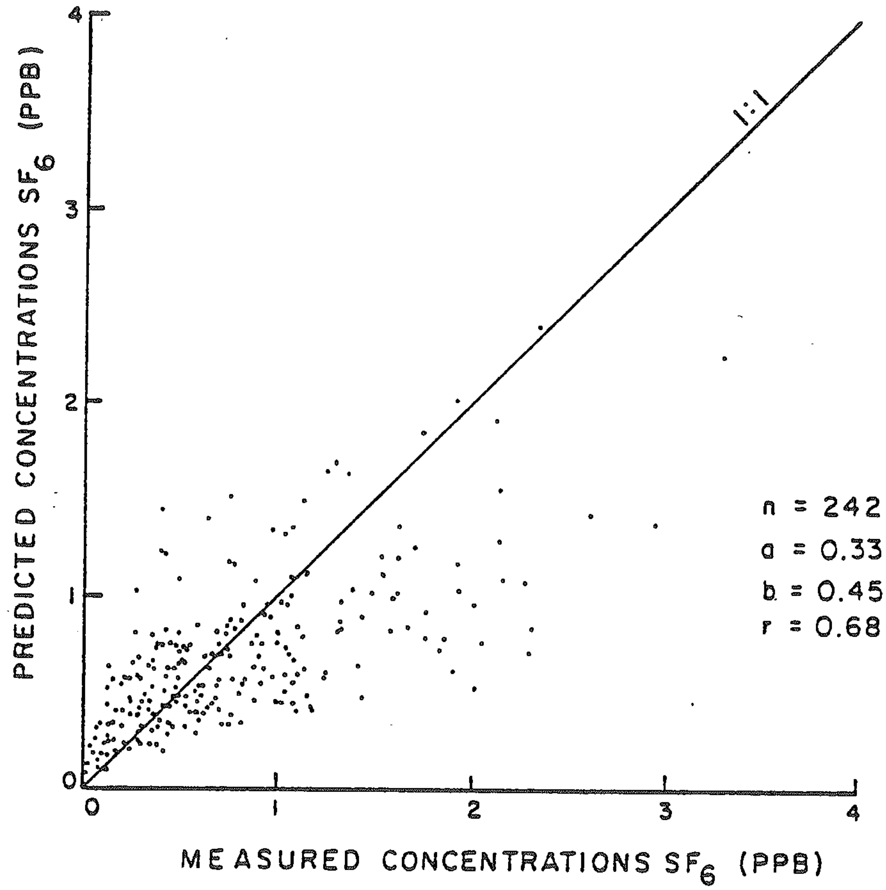
Surface Roughness:	ZO =	250	(cm)
Averaging Time:	ATIM =	30	(min)
Width:	W =	32	(m)
Link Length:	Y1,Y2 =	2500, -2500	(m)
Mixing Height:	MIXH =	1000	(m)
	VS,VD,AMB,H,X1,X2,YR =	0	
	U(@ 4.5m),BRG,CLAS,VPH,EF,XR,ZR =	variable	

The atmospheric stability classes (CLAS) used were taken from Chock(21). These were based on Golder's classification scheme(22).

The value of ZO used for this validation analysis is much greater than the value of 3 cm given by Chock(21). The lower value was the result of meteorological observations made within the relatively smooth swath of ground where the sampling probes were laid out. For crosswind conditions the 3 cm value is the proper value to use. For CALINE3, however, this is unimportant since the model is insensitive to Z0 for crosswind conditions. It was felt that a Z0 more characteristic of the densely wooded terrain surrounding the track would be more appropriate for parallel wind conditions(23).

A total of 38 half hour runs were chosen from the GM data base. Twenty-two of these runs occurred during unstable atmospheric conditions (B and C stability), while 16 occurred during stable conditions (E and F stability). Representative cases for near parallel and crosswind conditions were included for both stable and unstable conditions. The overall results of predicted versus measured values were plotted for the three downwind towers and two extended ground level probes for a total of 11 probes (except where measured data were missing). The results for unstable conditions are shown in Figures 28 and 29. A tendency for underprediction of higher measured concentrations and a more excessive scatter in results is exhibited for the CALINE2 model. For each graph the number of data points (n), the intercept (a), slope (b), and correlation coefficient (r) for a linear least squares regression are given. The results for stable conditions (see Figs. 30 and 31) are particularly revealing of the problems inherent in CALINE2. Extreme overpredictions are made by CALINE2 for over half of the 174 comparisons made. On the other hand, CALINE3 exhibits a relatively consistent performance with a slight tendency to overpredict.

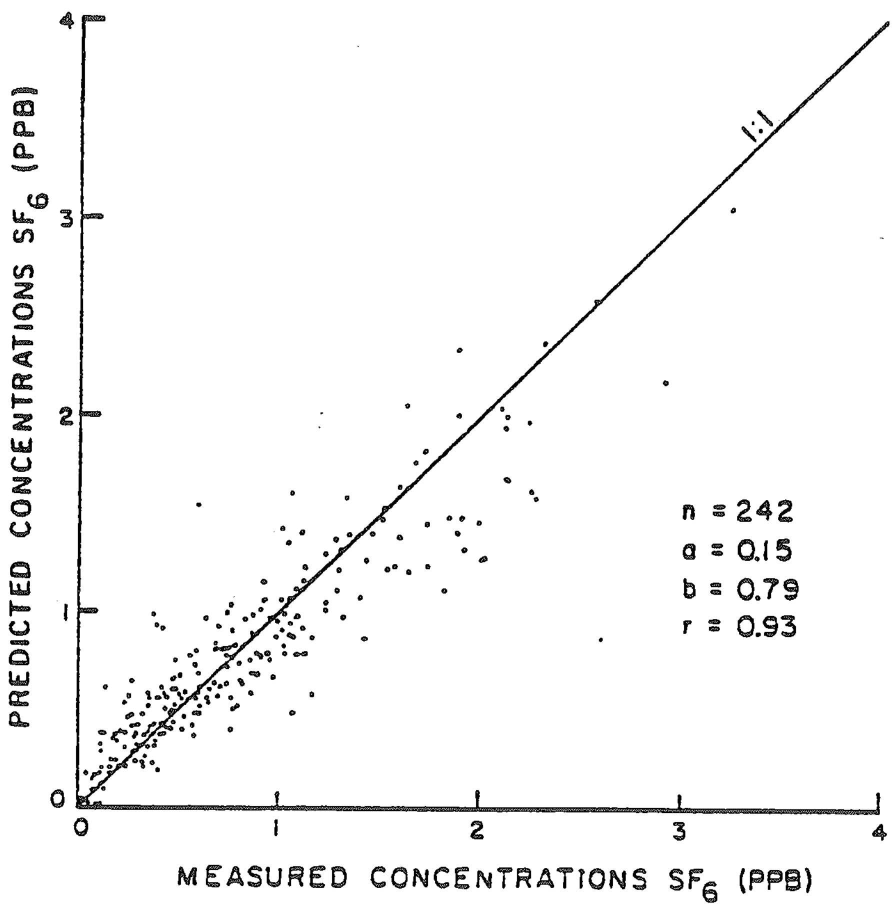
There are three reasons for the extreme overpredictions calculated by CALINE2. First, CALINE2 always assumes a 5 mile upwind length of highway, whereas for the GM study there was only a 2.5 kilometer upwind length. Second, by modeling elements using a virtual point source, CALINE2 does not realistically simulate



PREDICTED VS MEASURED CONCENTRATIONS SF_6 (PPB)

DATA BASE: GM
MODEL: CALINE2
STABILITY: B & C

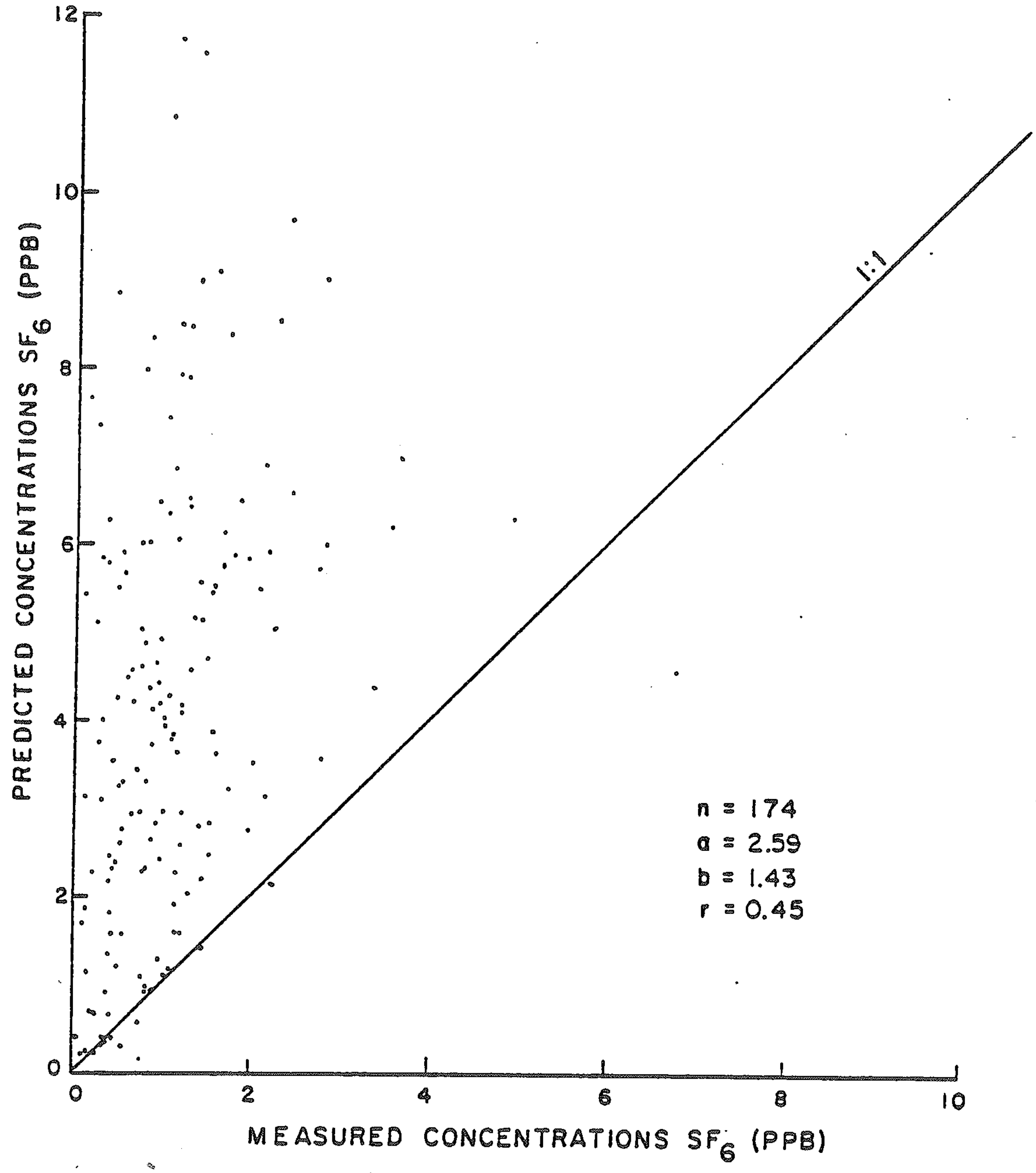
FIGURE 28



PREDICTED VS MEASURED CONCENTRATIONS SF_6 (PPB)

DATA BASE: GM
MODEL: CALINE3
STABILITY: B & C

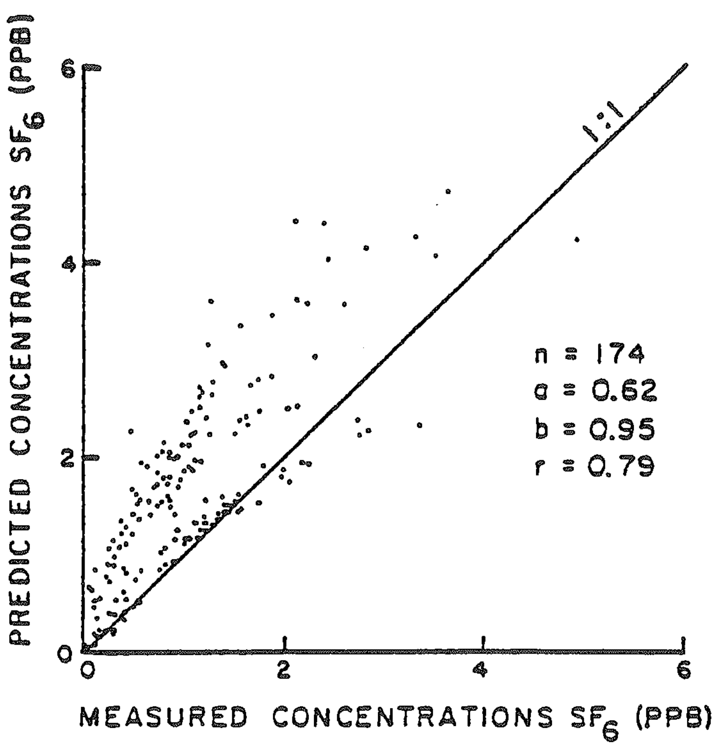
FIGURE 29



PREDICTED VS MEASURED CONCENTRATIONS SF_6 (PPB)

DATA BASE: GM
MODEL: CALINE2
STABILITY: E & F

FIGURE 30



PREDICTED VS MEASURED CONCENTRATIONS, SF_6 (PPB)

DATA BASE: GM
MODEL : CALINE3
STABILITY: E & F

FIGURE 31

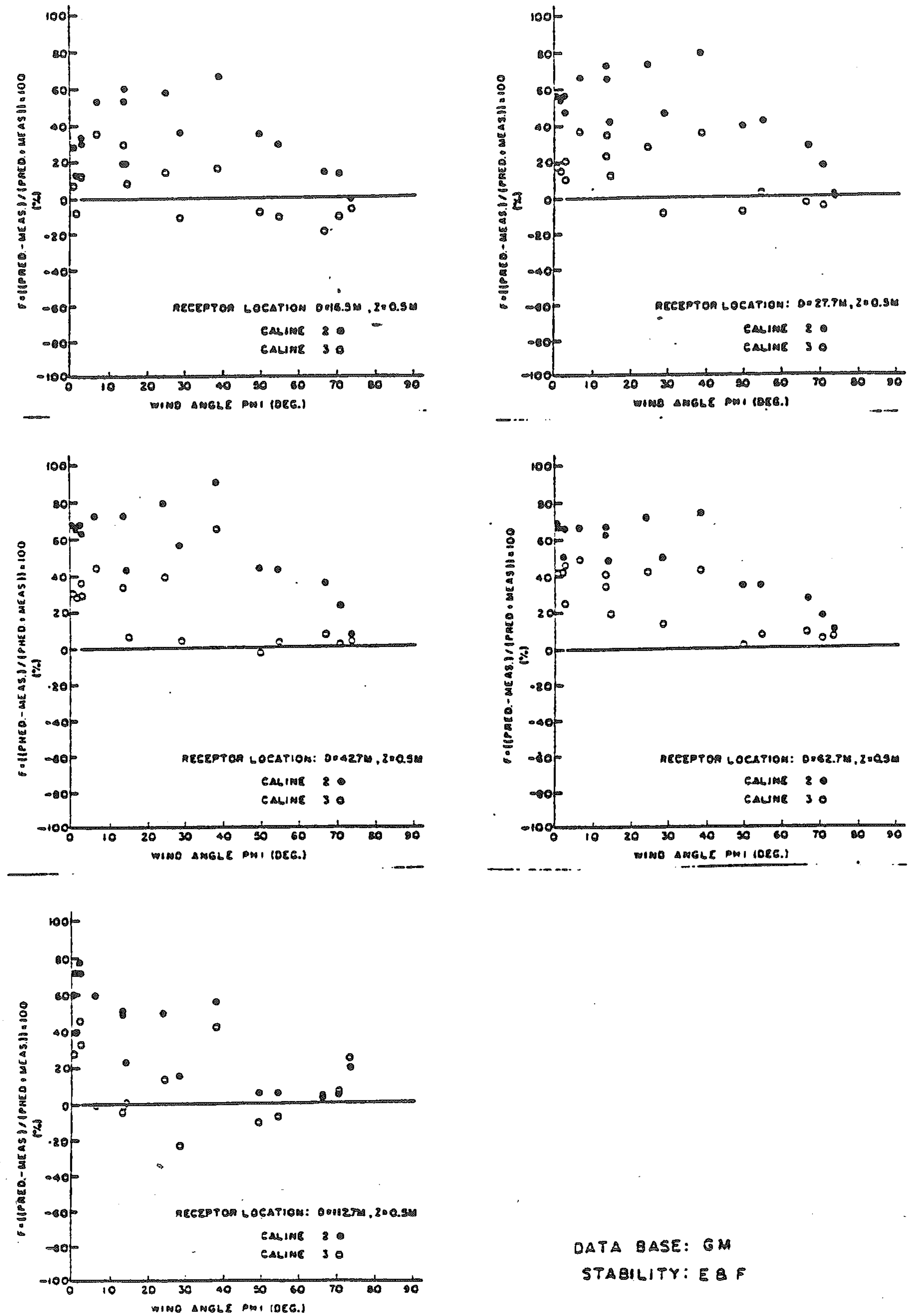
the initial horizontal dispersion of pollutants across the highway. Third, the vertical and horizontal dispersion curves used by CALINE2 have no adjustments for averaging time and surface roughness. They are based on ATIM=3 to 10 minutes and Z0=3 cm, and therefore yield extremely conservative estimates. All these deficiencies are corrected in the CALINE3 program.

The comparison factor analysis shown in Figure 32 gives an excellent picture of model performance as a function of wind angle. This analysis was performed solely for ground level receptors under stable atmospheric conditions. Ideal model performance is indicated by a comparison factor value of 0.

The superior performance of CALINE3 is evident. The plotted values of F for CALINE3 never exceed 50 (equivalent to P/M=3). The values for CALINE2 approach, and in one case exceed 80 (equivalent to P/M=9). It should be remembered that large values of F tend to be less critical for distant receptors with low concentrations. The tendency of CALINE2 to overpredict parallel wind cases is shown by the right to left upward trend for values of F at each receptor location. This pattern is also observed in the CALINE3 results, but is definitely less significant.

7.2 Stanford Research Institute Data Base

The site chosen for the Stanford Research Institute (SRI) field study was located along U.S. Highway 101 in Santa Clara, California. The highway is a six lane, at-grade section with an approximate 10 meter median strip. It carries a relatively high volume of traffic (around 100,000 ADT) with traffic speed and directional volume varying considerably throughout the day.



COMPARISON FACTOR F (%) VS WIND ANGLE (DEG)

FIGURE 32

The area surrounding the sampling location for a radius of .75 kilometer is essentially flat and composed of level fields containing short grasses. Monitoring was carried out during selected days in January and February of 1975.

Eight ground level probes (z = 1 meter) were located on each side of the highway along a line perpendicular to the highway. Two vertical probe arrays were also located on either side of the highway with probes situated at elevations of 1, 3, 6.1 and 13.6 meters. Samples were taken using sequential multibag samplers, thus obtaining integrated hourly air samples. Two vans were equipped to release two types of tracer gases, sulfur hexafluoride (SF_6) and freon-13B1. Concentrations of the two tracer gases, methane and nonmethane hydrocarbons, and carbon monoxide were measured at each sampling location.

Because of the small number of tracer vehicles and variable traffic conditions it was felt best to validate CALINE3 using the CO results rather than the tracer concentrations. Also, since the traffic speeds and volumes varied with the direction of flow, the site was modeled as two separate links or sources by both CALINE2 and CALINE3.

Emission factors given in the SRI data base were based on EPA Supplement 5 Methodology adjusted by the tracer results. It was decided to use Mobile Source Emission Factors dated March 1978 rather than those given in the data base because of the results of a mass balance analysis made for crosswind conditions at the closest downwind tower. This analysis indicated that the adjusted CO emission factors contained in the data base were too low to account for the measured concentrations. It was also felt that this would give a qualitative appraisal of the variability added to the final result by an emission factor model.

The inputs used to derive the emission factors were as follows:

TABLE 4

SRI Emissions Input Parameters

Calendar Year:	1975	
Cold Starts:	20%	
Hot Starts:	27%	
Vehicle Mix:	LDA =	81.5%
	LDT =	12.1%
	MDT =	1.3%
	HDG =	4.5%
	HDD =	.5%
	MC =	.1%
Vehicle Speed:	variable	
Ambient Temperature:	variable	

The input values used for CALINE2 and CALINE3 were as follows:

TABLE 5

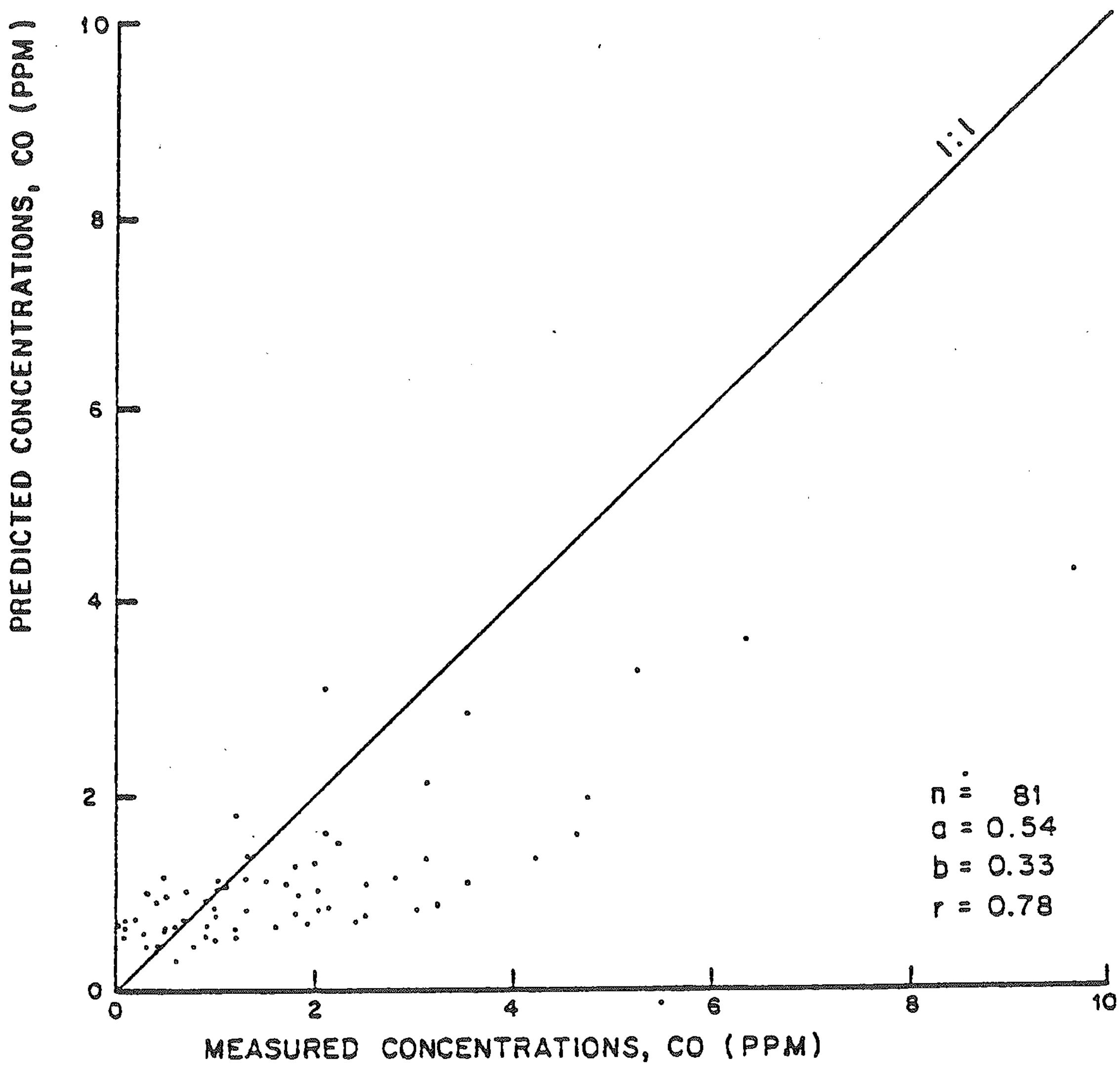
SRI CALINE Input Parameters

Surface Roughness:	ZO =	10	(cm)
Averaging Time:	ATIM =	60	(min)
Width:	W =	20.6	(m/link)
Link Length:	Y1,Y2 =	3000, -3000	(m)
Mixing Height:	MIXH =	1000	(m)
	VS,VD,AMB,H,X1,X2,YR =	0	
	U(@ 3.8m),BRG,CLAS,VPH,EF,XR,ZR =	variable	

The overall analysis was divided into unstable, neutral, and stable atmospheric stability classes. These classes were determined using the same Golder classification scheme that was used for the GM data. The number of hourly runs studied for each atmospheric stability class were, respectively, 9, 11, and 8. For each of these runs, 5 ground level and 6 elevated probes were modeled (except where data were missing). The measured CO value at each of these downwind probe locations was adjusted for upwind ambient CO levels. Nearly parallel winds were not well represented, with only one hourly run having a wind angle with respect to the highway less than 25 degrees.

The overall results for unstable conditions are shown in Figures 33 and 34. While both models tend to underpredict at the higher concentration (probes located closer to the road) this tendency is less marked for CALINE3. The results for neutral atmospheric stability conditions, shown in Figures 35 and 36 indicate a reasonable overall trend by both models, but an excessive amount of scatter for CALINE2. Again, CALINE3 has a tendency to underpredict for receptors close to the road, but this tendency is less than for the unstable case. For stable atmospheric conditions, (see Figures 37 and 38), the superiority of CALINE3 is apparent (note the scale difference between the two graphs). CALINE3 is slightly conservative, but considerably more accurate than CALINE2.

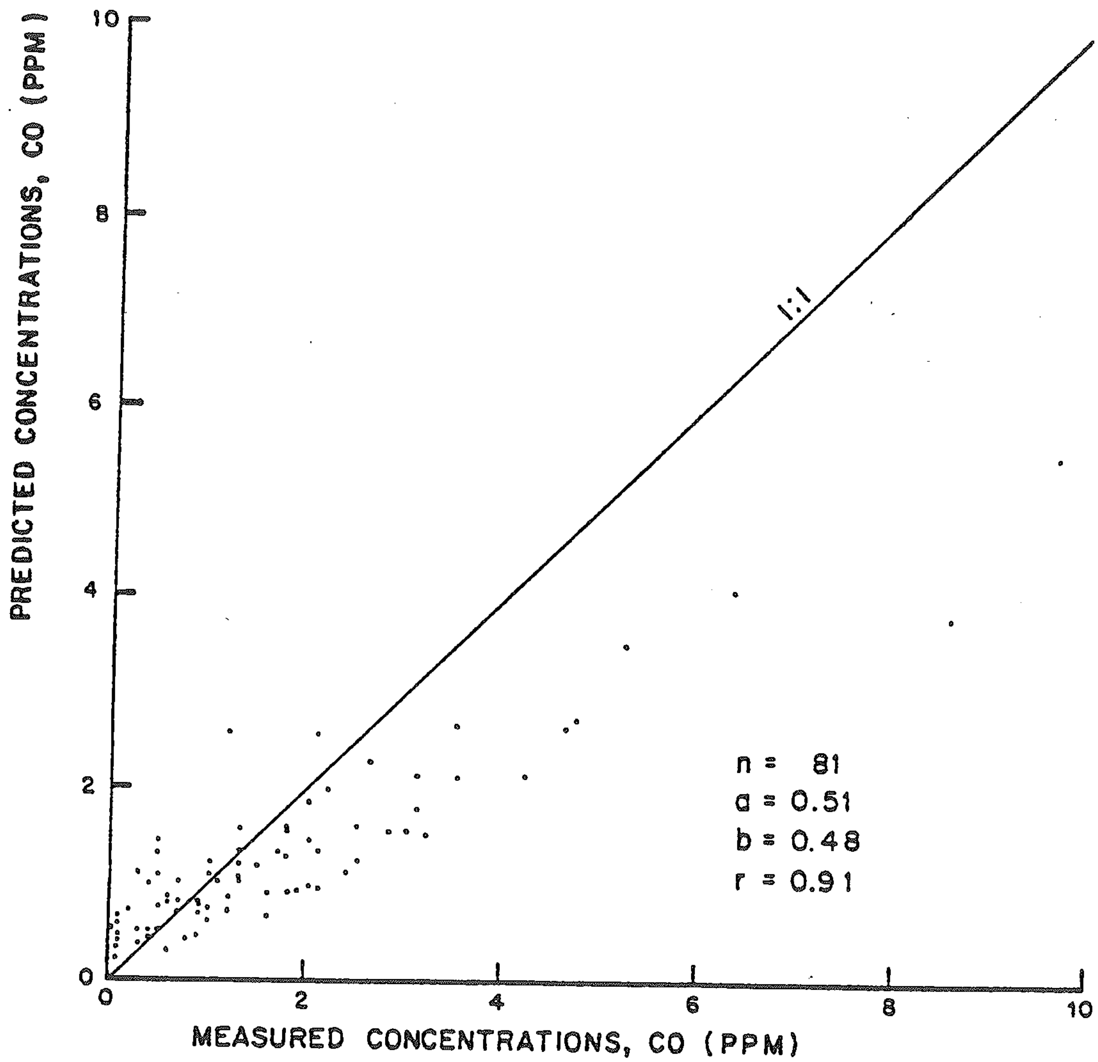
By comparing the overall results for the GM and SRI data bases, it can be seen that the use of an emissions model for the SRI analysis has not added significantly to the variability of the final model result.



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SRI
MODEL: CALINE2
STABILITY: A & C

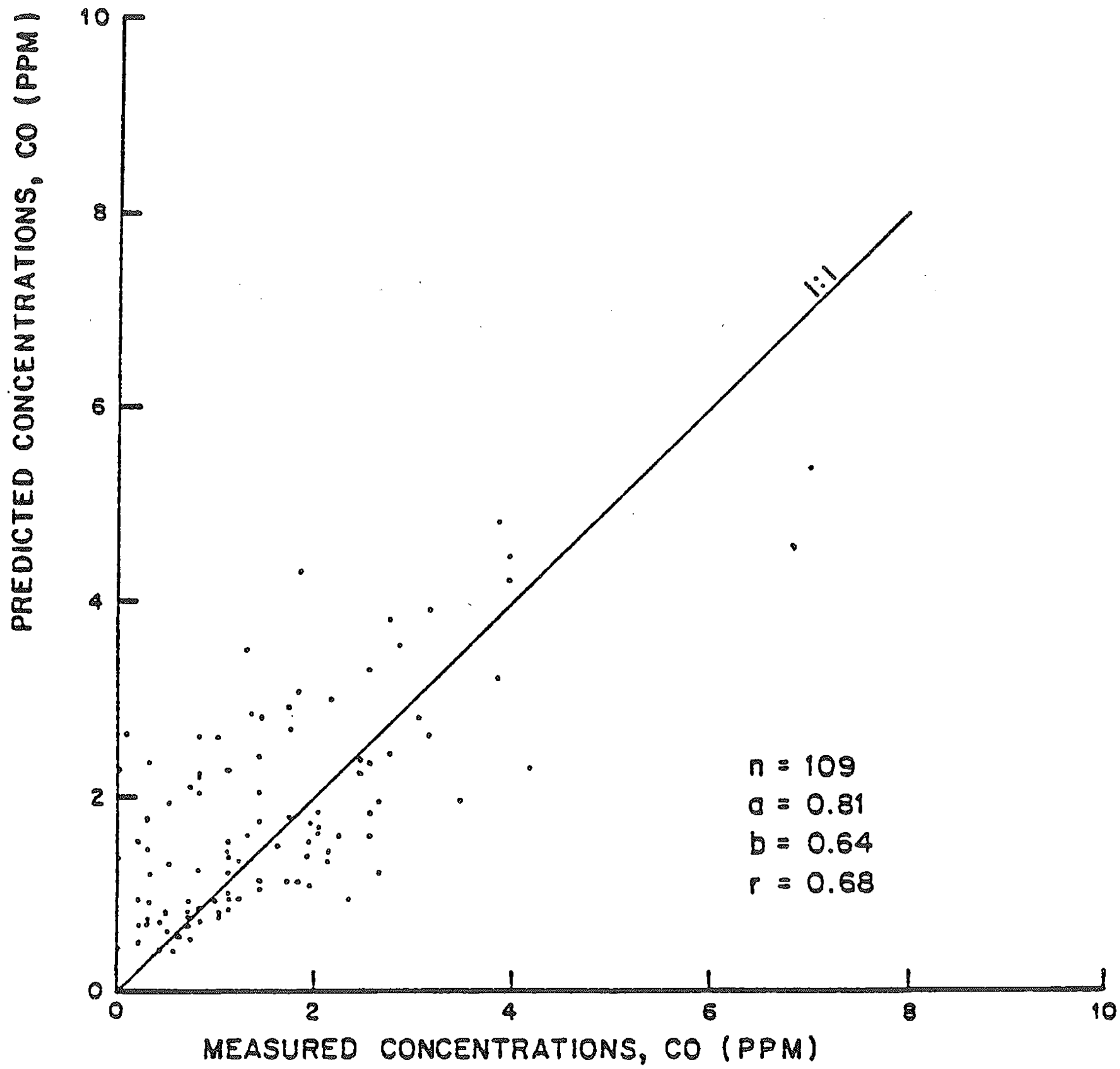
FIGURE 33



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SRI
MODEL: CALINE3
STABILITY: A & C

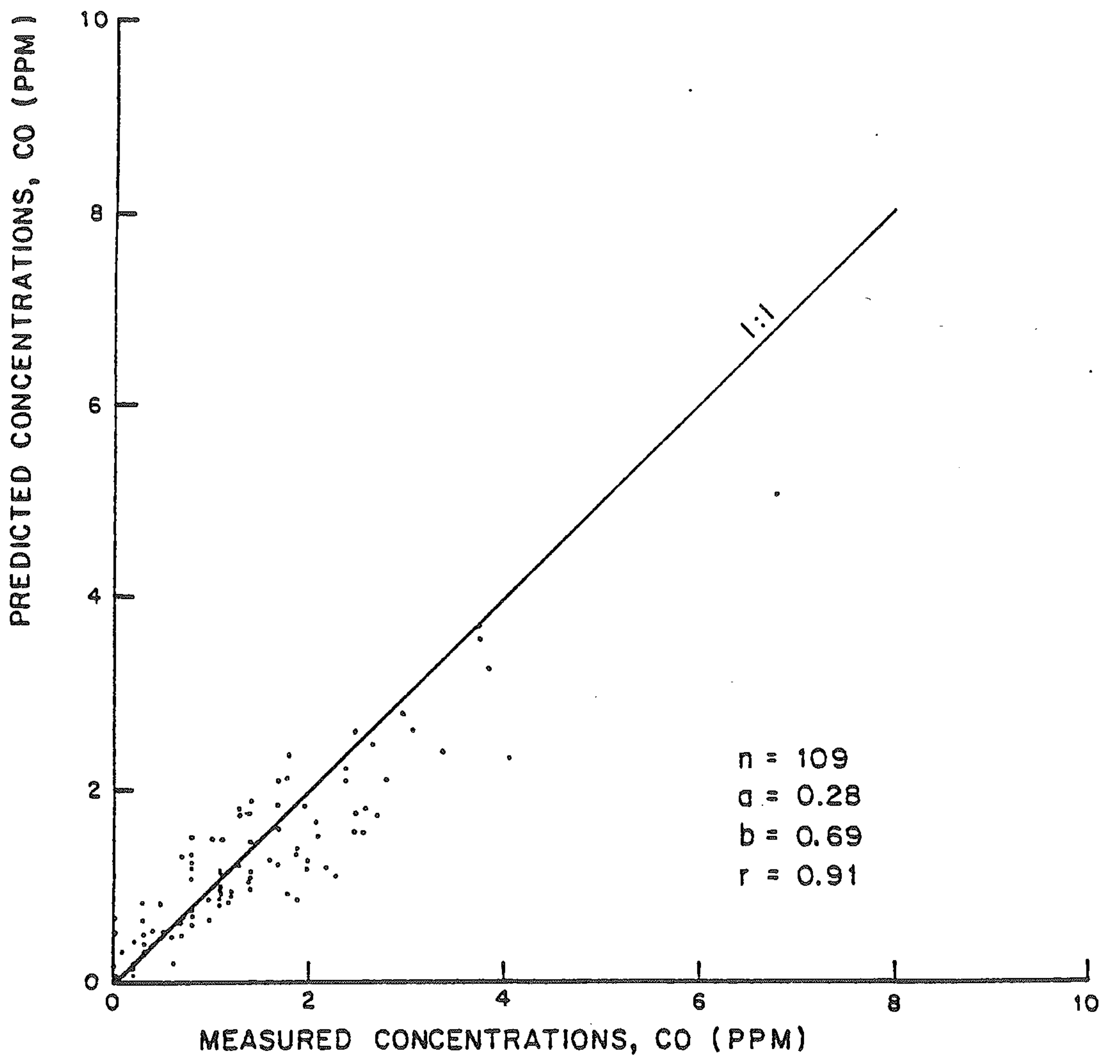
FIGURE 34



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SRI
MODEL: CALINE2
STABILITY: D

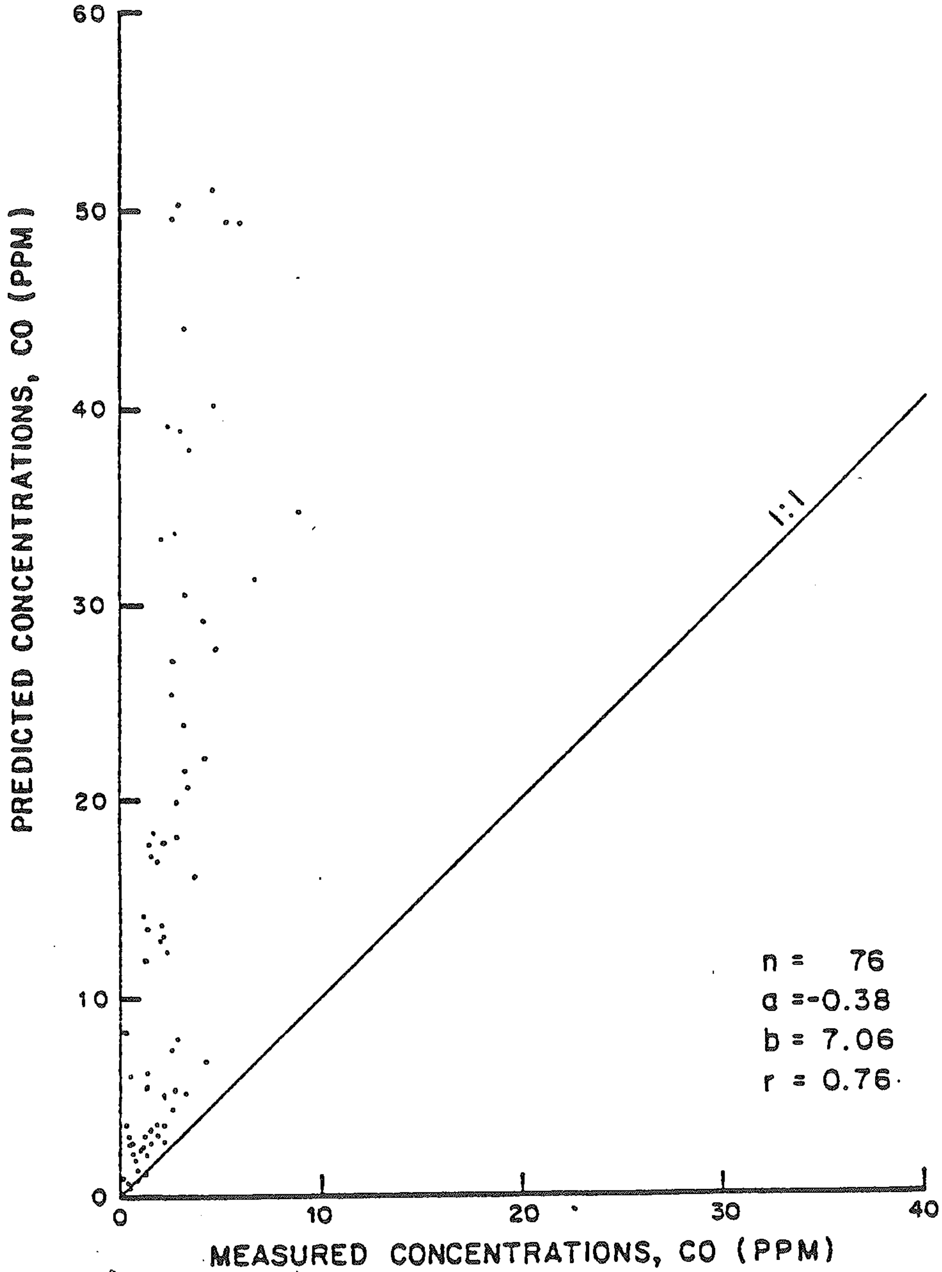
FIGURE 35



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SRI
MODEL: CALINE3
STABILITY: D

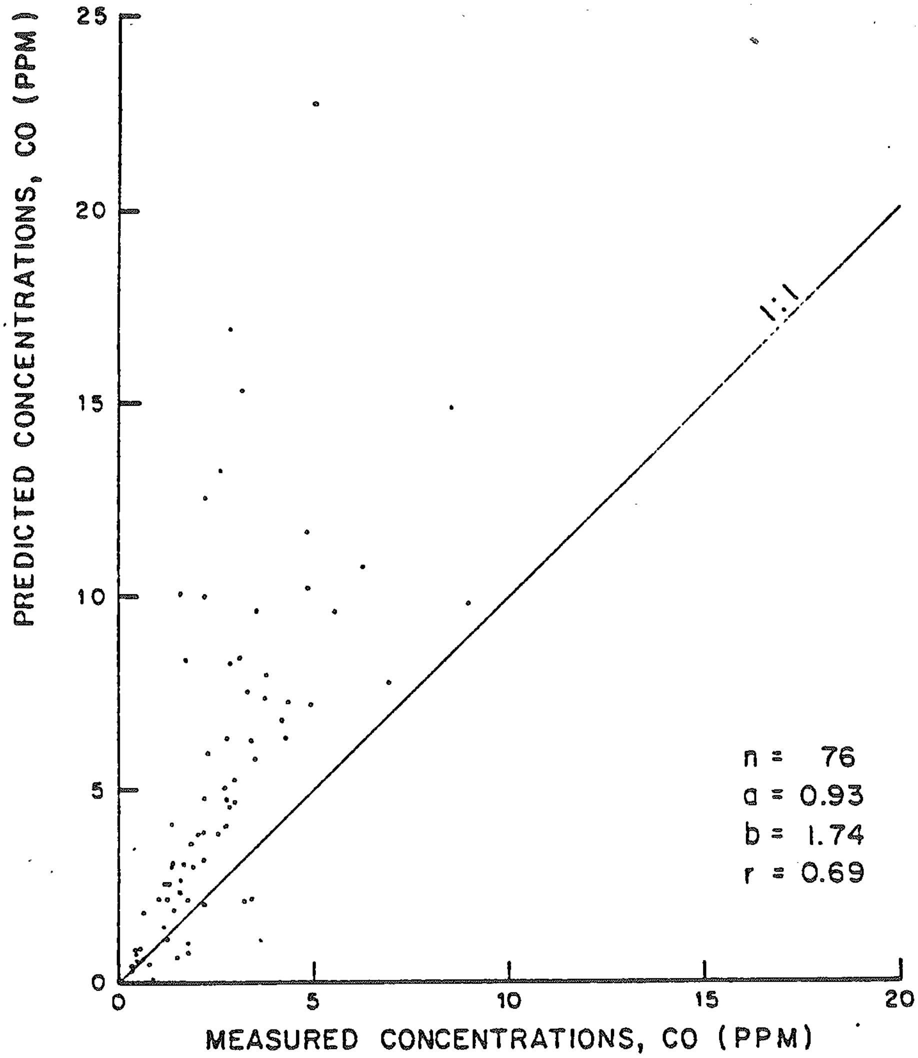
FIGURE 36



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SR1
MODEL: CALINE2
STABILITY: E & F

FIGURE 37



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: SRI
MODEL: CALINE3
STABILITY: E & F

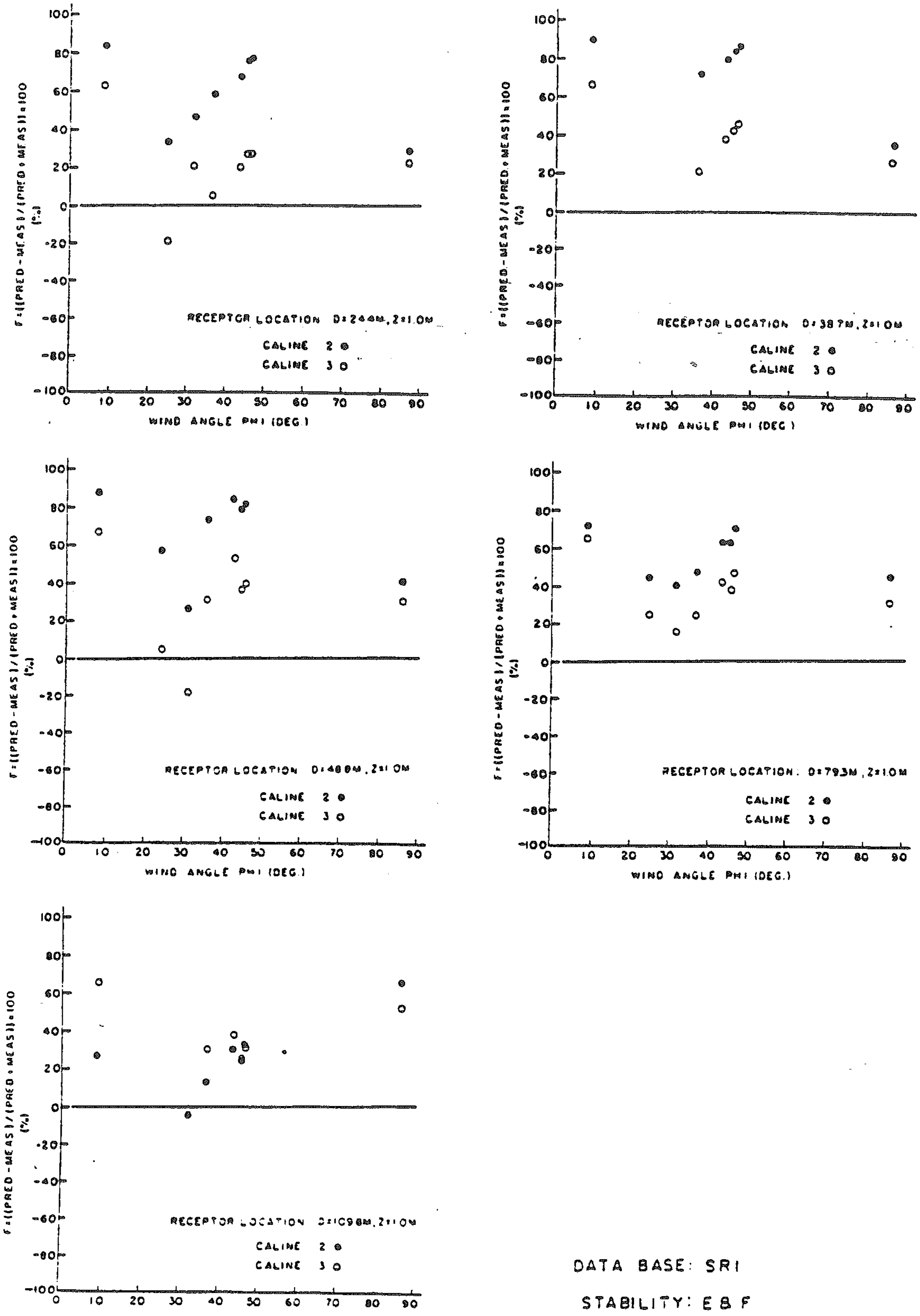
FIGURE 38

Inspection of the comparison factor graph for ground level receptors under stable conditions (see Fig. 39), again reveals the superiority of CALINE3 over CALINE2. With only one true parallel wind case it is difficult to assess the performance of the models as function of wind angle. The overprediction for that one case could be attributed to significant concentrations spreading from the highway to the upwind (ambient) sampling site causing an overestimate of the ambient concentration. At the distant receptors, the differences between the two models seem to vanish. This is probably due to the increased error of field measurements as a fraction of the measured value for low concentrations (creating more "noise" in the data), and the tendency of CALINE2 to disperse pollutants less horizontally than CALINE3.

7.3 Los Angeles Data Base

During 1974 and 1975 the California Department of Transportation conducted a detailed monitoring program for pollutants near freeways in the Los Angeles area. Detailed meteorological and aerometric data were collected at several sites and summarized on the Department's Air Quality Data Handling Svstem (AQDHS). The amount of data collected was considerably more extensive than either the GM or SRI data bases, thereby allowing a wider choice of specific meteorological conditions.

Two sites, a depressed section (Site 1) and an elevated section (Site 3), were chosen for the verification study. The probe layouts and highway geometry for the two sites are shown in Figures 40 and 41. CO data from the downwind probes at each site were used for the overall and comparison factor analyses. Fifty-three hourly runs from Site 1 and forty hourly runs from



DATA BASE: SRI

STABILITY: E & F

COMPARISON FACTOR F (%) VS WIND ANGLE (DEG)

FIGURE 39

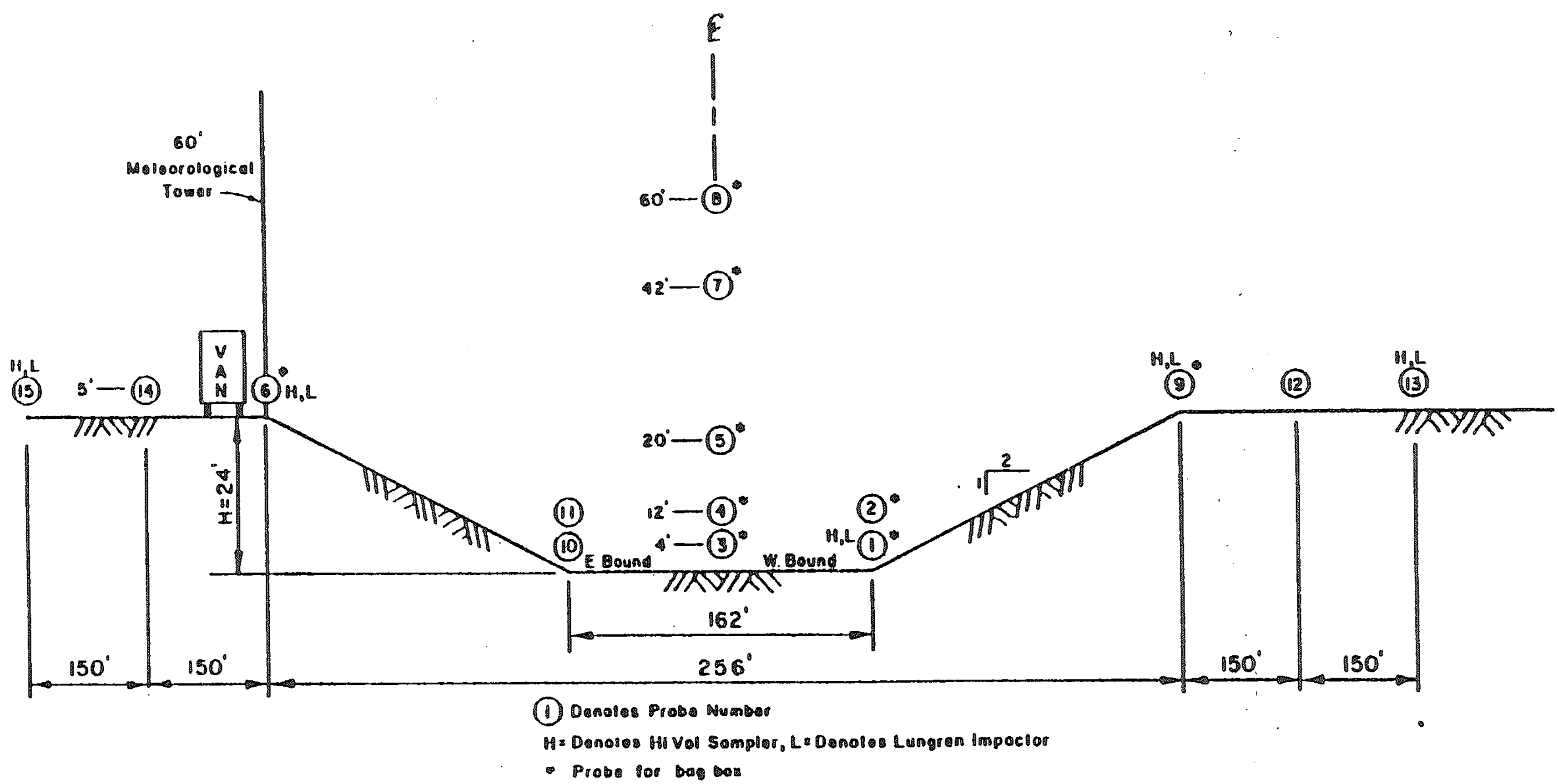
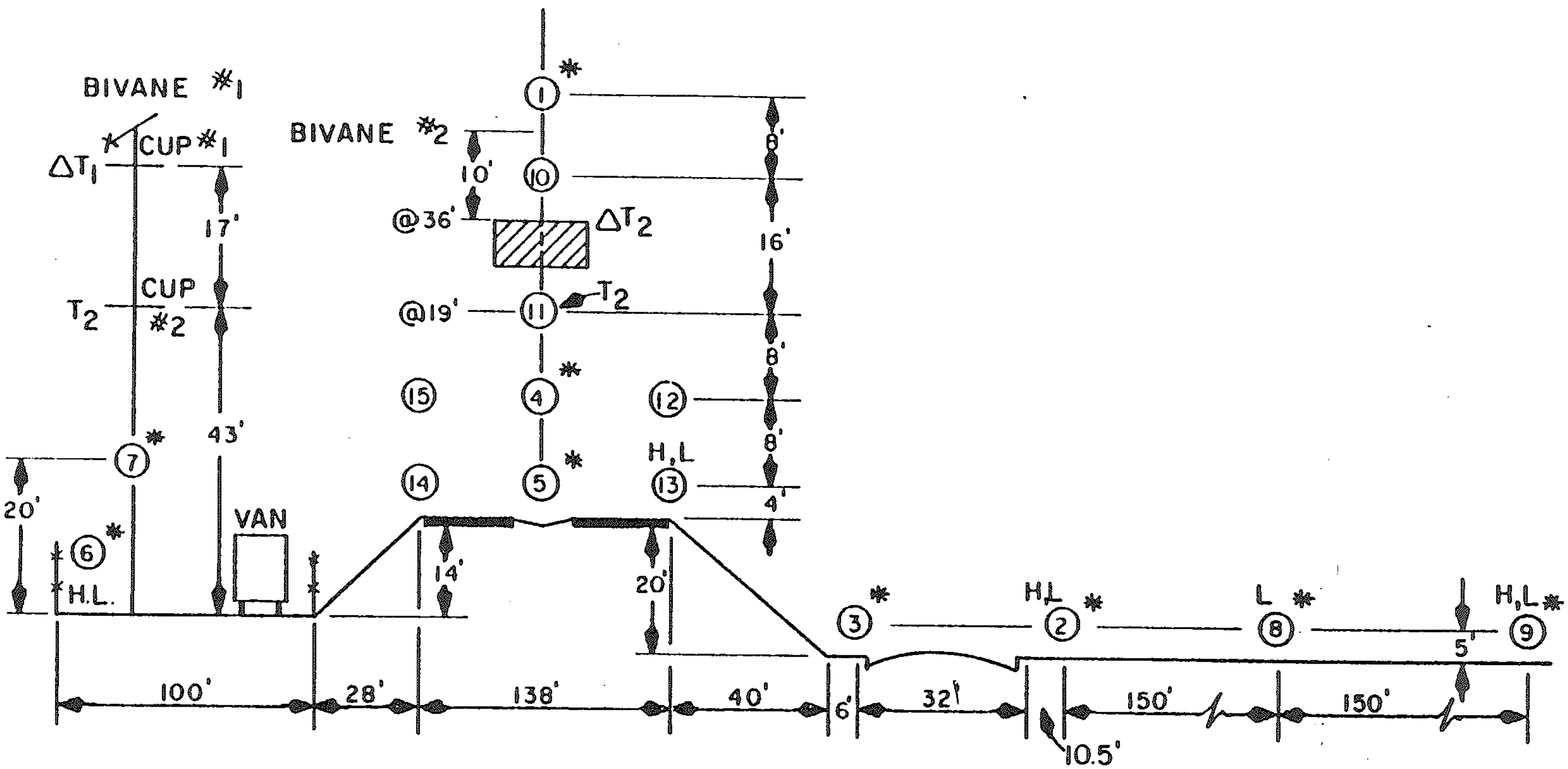


FIG. 3 PROBE LOCATIONS (SITE I)
SANTA MONICA FWY. AT 4TH AVE. P.O.C.
NOV. 1, 1973 TO JUNE 12, 1974
(NOT TO SCALE)

FIGURE 40



LEGEND

③ = PROBE NUMBER
$\ast$ = PROBE FOR BAG BOX
L = LUNDGREN IMPACTOR
H = HI VOL SAMPLER

FIG. 5 PROBE LOCATIONS, SITE 3, SAN DIEGO FWY. AT 134TH STREET (1974-75)

(NOT TO SCALE)

FIGURE 41

Site 3 were chosen. Wind angles varied from 20 to 90 degrees with respect to the roadway. Stability classes B, D and F were represented for each site.

As with the SRI data base, Mobile Source Emission Factors, dated March 1978, were used as inputs to both models. The emission factors were computed assuming the following conditions:

TABLE 6

LA Emissions Input Parameters

Calendar Year:	1975
Cold Starts:	6%
Hot Starts:	2%
Vehicle Mix:	LDA = 77.0%
	LDT = 11.6%
	MDT = 1.4%
	HDG = 4.5%
	HDD = 4.5%
	MC = 1.0%
Vehicle Speed:	variable
Ambient Temperature:	variable

While traffic volume and speed varied depending on direction of flow for both sites, a single link computation using a weighted emission factor was used for both models. This permitted evaluation of model performance for a single link approximation.

The following input values were used to run the models:

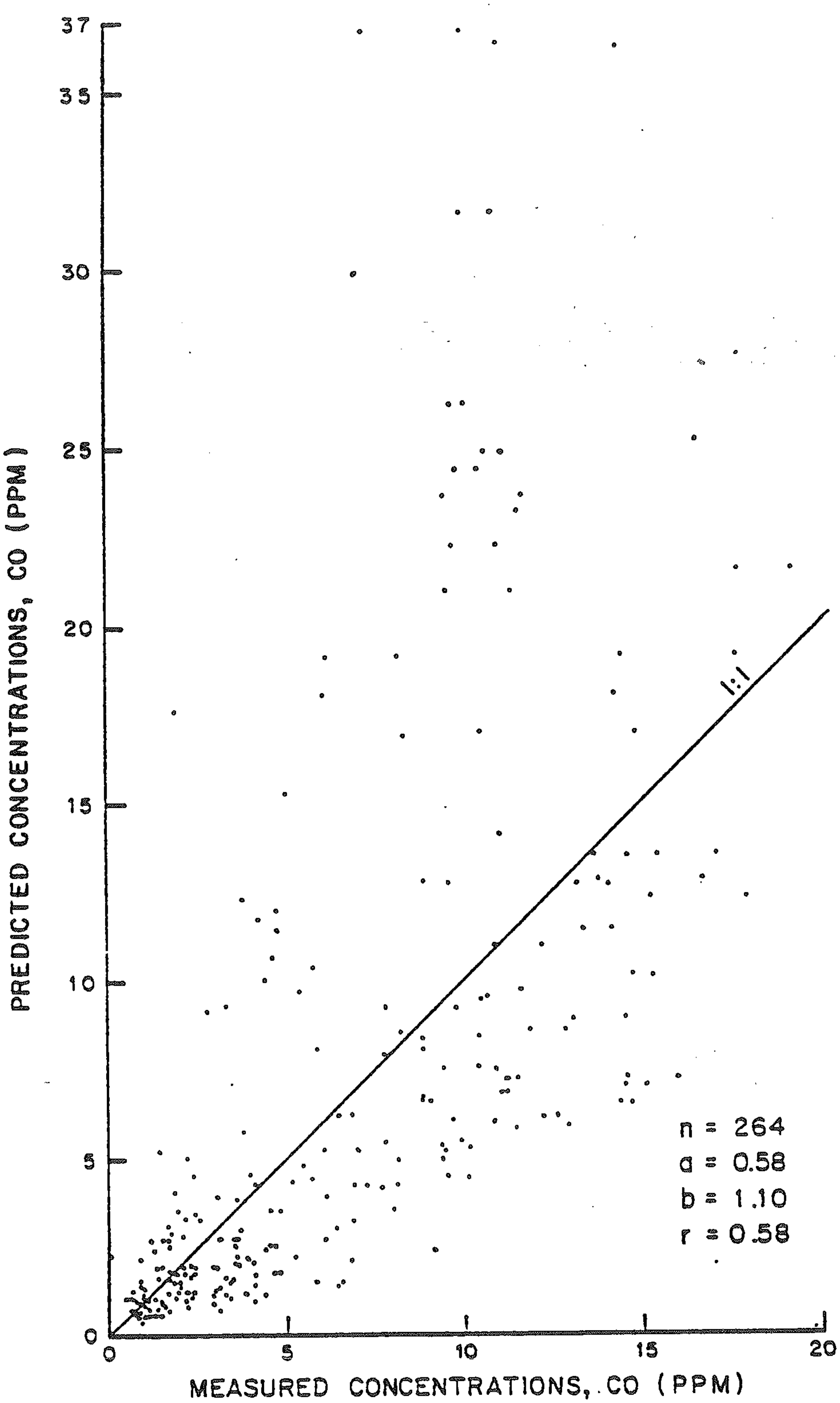
TABLE 7

LA CALINE Input Parameters

Surface Roughness:	ZO =	100	(m)
Averaging Time:	ATIM =	60	(min)
Width:	W =	48.8	(m-Site 1)
	W =	42.1	(m-Site 3)
Link Length:	Y1,Y2 =	2500, -2500	(m)
Height:	H =	-7.3	(m-Site 1)
	H =	6.1	(m-Site 3)
Mixing Height:	MIXH =	1000	(m)
	VS,VD,AMB,X1,X2,YR =	0	
	U(@ 13.4m),BRG,CLAS,VPH,EF,XR,ZR =	variable	

The overall analysis was performed for downwind ground level probes including the 4 ft probe at the downwind edge of the roadway. This resulted in an analysis of 4 probes for Site 1 and 5 probes for Site 3. The measured CO readings at these probes were adjusted for ambient by using the distant upwind ground level receptor results. Turner's stability classification method was used to determine the hourly values for CLAS(6).

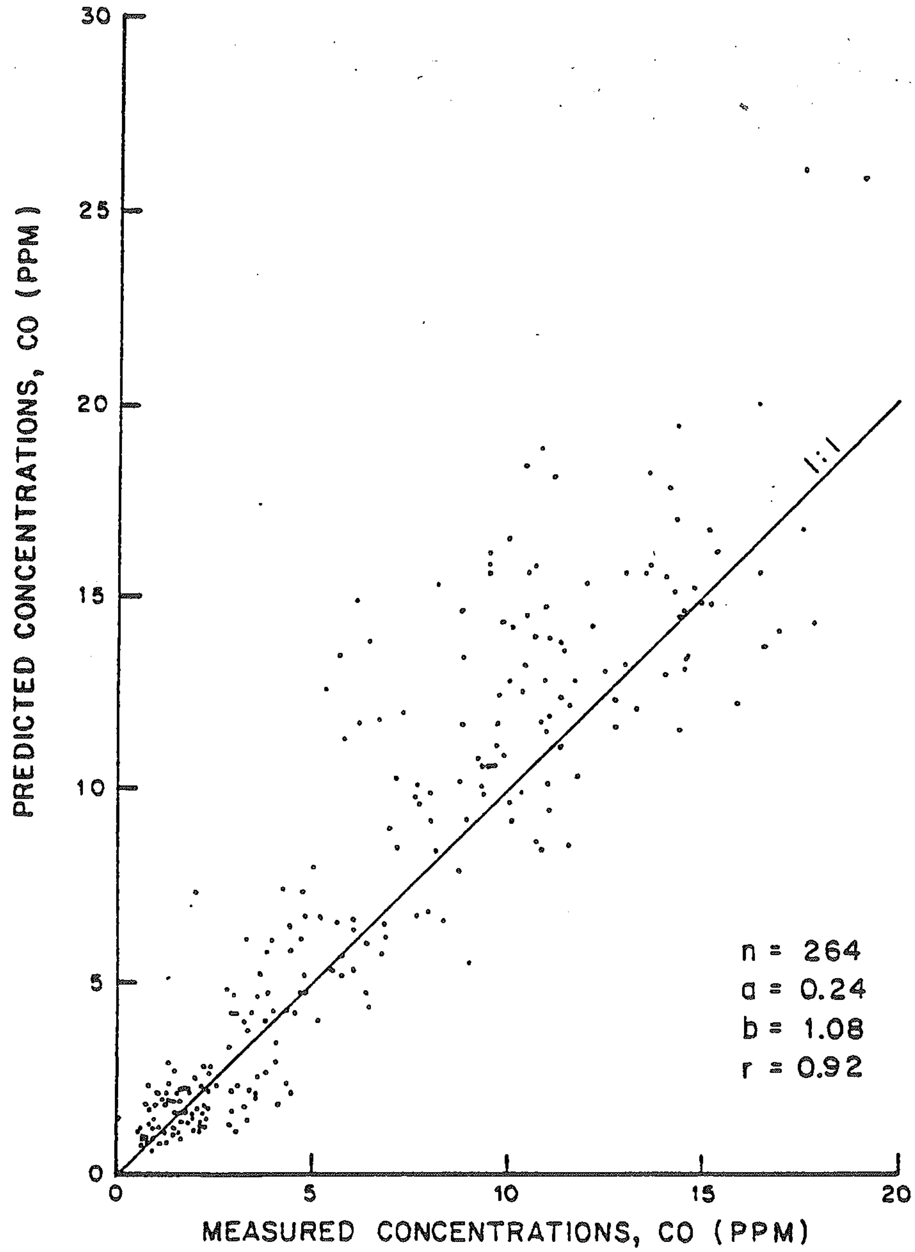
The overall analysis for Site 1 shown in Figures 42 and 43 indicates significantly greater variability in the CALINE2 results than the CALINE3 results. It should be stated, however, that the CALINE3 depressed section algorithm was indirectly based on Site 1 measurements. CALINE2 uses an empirical reduction factor which is a function of the depth of the depressed section and is applied equally to all predicted concentrations. The CALINE3



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: LA, SITE 1
MODEL: CALINE2
STABILITY: B, D, F

FIGURE 42



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: LA, SITE 1
MODEL: CALINE3
STABILITY: B, D, F

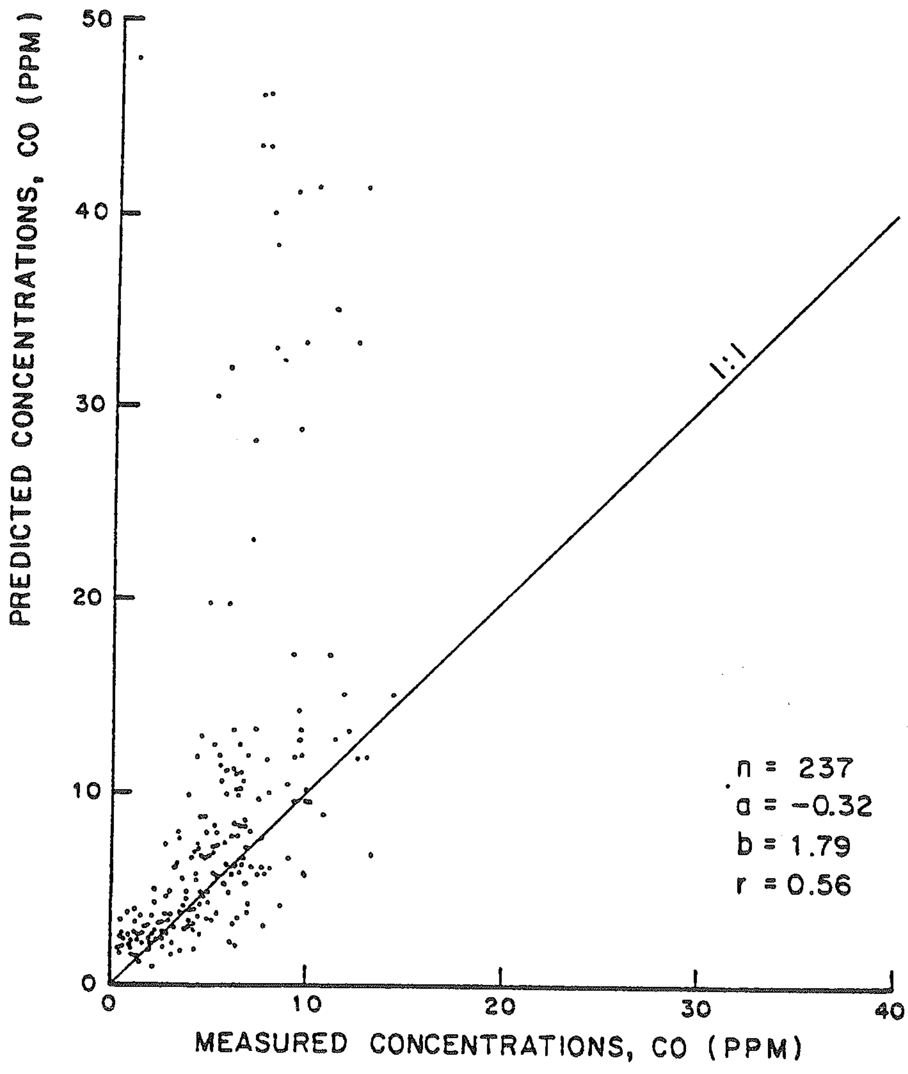
FIGURE 43

algorithm, however, generates higher predicted concentrations within the depressed section and lower values away from the depressed section. This approach seems to yield better results.

For Site 3 the results shown in Figures 44 and 45 again show the tendency of CALINE2 to grossly overpredict (note scale difference). The extreme overpredictions occur for the higher measured concentrations (probes located closer to the roadway). The underpredictions by CALINE3 for high measured concentrations occur primarily under crosswind conditions at probe 3 which is located immediately in the lee of the fill section. These underpredictions, which can be more clearly seen in the comparison factor analysis, apparently result from back eddying effects created by the crosswind flow of air over the fill section. The underpredictions were much worse before it was decided to have the model set H=0 for fill sections.

The comparison factor graphs for Site 1 (see Fig. 46) reveal little concerning model response to wind angle because of the limited range of wind angles available for F stability conditions. For wind angles around 20°, however, the shift from overprediction to underprediction as a function of receptor distance can clearly be seen for CALINE2. CALINE3 yields more consistent, slightly conservative values for each of the probe locations. CALINE3 may also be exhibiting a slight tendency towards overprediction for more parallel winds. These overpredictions are not very large, however, and could perhaps be lessened even more if onsite measurements of horizontal wind angle variation were used to derive the horizontal dispersion curves used in the model.

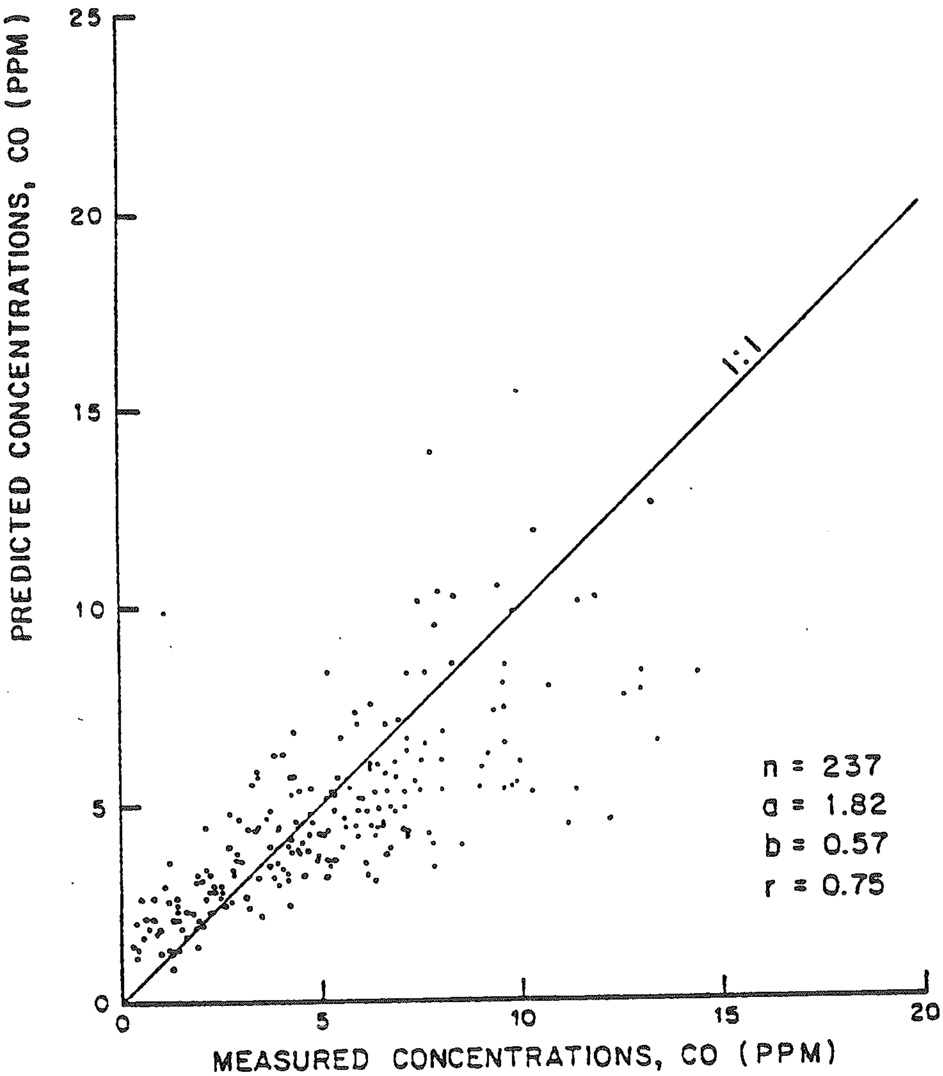
In Figure 47 the comparison factor results for Site 3 are shown. The tendency for underprediction by both models for



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: LA, SITE 3
MODEL: CALINE2
STABILITY: B, D, F

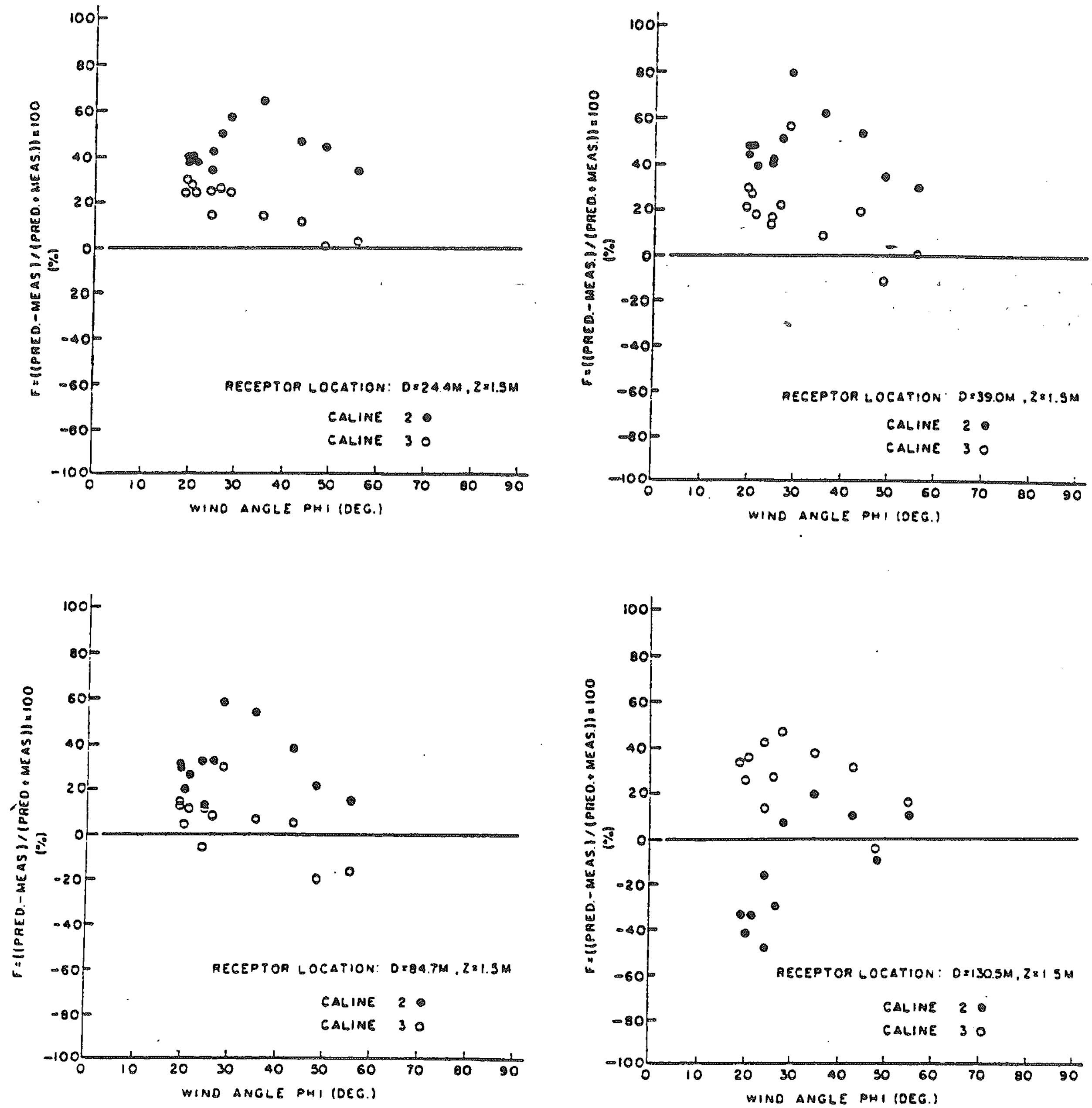
FIGURE 44



PREDICTED VS MEASURED CONCENTRATIONS, CO (PPM)

DATA BASE: LA, SITE 3
MODEL: CALINE3
STABILITY: B, D, F

FIGURE 45

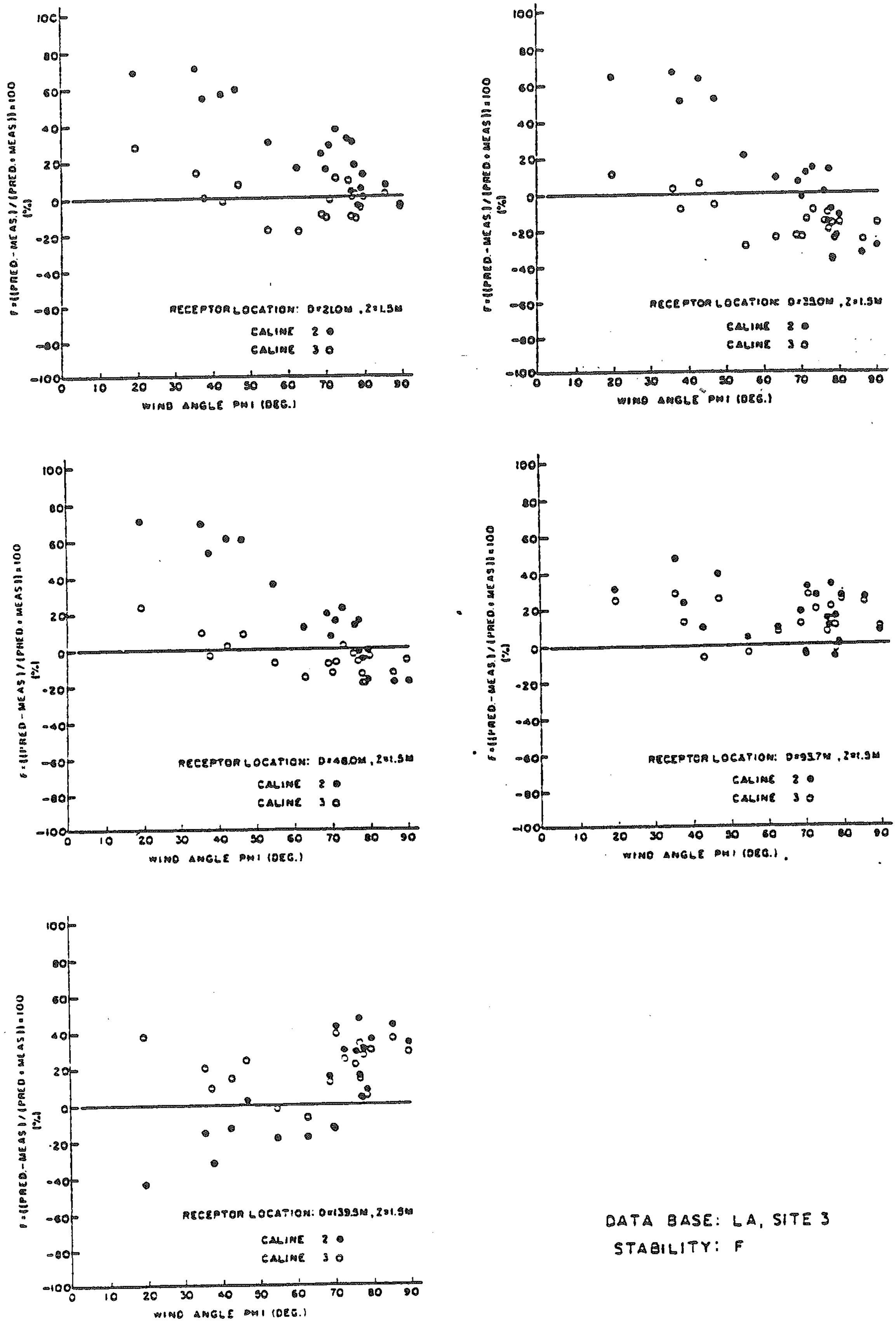


DATA BASE: LA, SITE I

STABILITY: F

COMPARISON FACTOR F (%) VS WIND ANGLE (DEG)

FIGURE 46



DATA BASE: LA, SITE 3
STABILITY: F

COMPARISON FACTOR F(%) VS WIND ANGLE (DEG)

FIGURE 47

probe 3 under crosswind conditions can be seen. Again, the CALINE3 results are more consistent and less conservative than the CALINE2 results. CALINE3 shows a tendency towards higher predictions for parallel wind cases, but these values are much lower than the CALINE2 results. As in the other verification analyses, the difference between the two models tends to lessen with increased receptor distance.

8. USER INSTRUCTIONS

8.1 Restrictions and Limitations

8.1.1 Core requirements: approximately 60K.

8.1.2 CALINE3 can process a maximum of 20 links per job. For each link, the following must remain constant: The section type (TYP$), the source height (HL), the mixing zone width (WL), the traffic volume (VPHL), and the emission factor (EFL). If for any reason one of the variables changes, it must be accounted for by a different link or an averaged value. In the case in which two links are parallel and identical, the two links may be considered as one with mixing zone width equal to the sum of the two traveled way widths plus the edge to edge median width plus 6 meters. The median width may not exceed 10 meters.

8.1.3 CALINE3 can process a maximum of 20 receptors per job.

8.1.4 For any job, CALINE3 can process an unlimited number of meteorological conditions.

8.1.5 In setting up link dimensions, the link length should always be greater than the link width.

8.1.6 Input variable limits:

Variable	Suggested and Mandatory Limits	Reason
Wind Speed	$U \geq 1$ m/s	Gaussian assumption; with $U \geq 1$ m/s, along-wind diffusion can be considered negligible relative to U.
Wind Direction	$0° \leq BRG \leq 360°$	Wind azimuth bearing measured relative to positive Y-axis.
Averaging Time	3 min $\leq ATIM \leq$ 120 min	Reasonable limits of power law approximation.
Surface Roughness	3 cm $\leq Z0 \leq$ 400 cm	Reasonable limits of power law approximation.
Mixing Zone	$W \geq 10$ m	Minimum of 1 lane plus 3 meters per side of link.
Link Length	$W \leq LL \leq 10$ km	Link length, as defined by link endpoint coordinates (X1,Y1,X2,Y2), must be greater than or equal to link width for correct element resolution, and less than or equal to 10 km since vertical dispersion curve approximations are only valid for downwind distances of 10 km or less.
Stability Class	CLAS=1,2,3,4,5,6	Pasquill stability class scheme.
Source Height	-10 m $\leq H \leq$ 10 m	Not verified outside of given range.
Receptor Height	$Z \geq 0$	Gaussian plume reflected at air-surface interface; model assumes plume transport over horizontal plane. NOTE: For depressed sections $Z \geq H$ (where H is negative) is permitted for receptors within the section.

8.1.7 The model should not be used in areas where the terrain in the vicinity of the highway is sufficiently rugged to cause significant spatial variability in the local meteorology.

8.1.8 The model should not be used for streets within a central business district where the so-called street canyon effect is significant.

8.2 Grid Orientation

CALINE3 uses a combination of the X-Y Cartesian coordinate system and the standard compass system to establish coordinate locations and link geometry. The standard, 360° compass is overlaid onto the X-Y coordinate plane such that north corresponds to the +Y direction and east corresponds to the +X direction. Wind angles (BRG) are measured as the azimuth bearing of the direction from which the wind is coming (i.e., BRG = 270° for a wind from the west). Coordinates, link height and link width may be assigned in any consistent length units. The user must input a scale factor (SCAL) to convert the chosen units to meters (SCAL=1. if coordinates and link height and width are input in meters).

The X-Y grid and compass systems are combined into a single system and may be used with north representing true or magnetic north or an assumed north. In either case, once north has been chosen, all angles and X-Y pairs must be consistently assigned. Negative coordinates are permitted.

8.3 Input (see Fig. 48)

Card Sequence Number	Variable Name	Variable Description*
1	JOB	Current job title**
	ATIM	Averaging time, in minutes***
	ZO	Surface roughness, in cm
	VS	Settling velocity, in cm/s
	VD	Deposition velocity, in cm/s; if the settling velocity is greater than 0 cm/s, the deposition velocity should be set equal to the settling velocity.
	NR	Number of receptors; $NR_{max}=20$ (Integer)
	SCAL	Scale factor to convert receptor and link coordinates, and link height and width to meters.
2	RCP	Receptor name
	XR	X-coordinate of receptor
	YR	Y-coordinate of receptor
	ZR	Z-coordinate of receptor
		NOTE: Card sequence "2" must appear NR times.

*Real variables, except titles, must contain a decimal point and integer variables are right justified.

**Data type real unless specified otherwise.

***See restrictions and limitations for additional information on variable limits.

Card Sequence Number	Variable Name	Variable Description
3	RUN	Current run title
	NL	Number of links; $NL_{max}=20$ (Integer)
	NM	Number of meteorological conditions; no maximum (Integer)
4	LNK	Link title
	TYP	Section type AG=At-Grade FL=Fill BR=Bridge DP=Depressed
	XL1, YL1	Coordinates of link endpoint 1
	XL2, YL2	Coordinates of link endpoint 2
	VPHL	Traffic volume in vehicles per hour
	EFL	Emission factor, in grams/mile
	HL	Source height
	WL	Mixing zone width
		NOTE: Card sequence number "4" must appear NL times.
5	U	Wind speed, in m/s
	BRG	Wind angle with respect to positive Y-axis in degrees; may range between 0°-360°, inclusive.
	CLAS	Atmospheric stability class, in numeric format (1-6=A-F) (Integer)

Card Sequence Number	Variable Name	Variable Description
5 (cont.)	MIXH	Mixing height, in meters
	AMB	Ambient concentration of pollutant, in ppm
		NOTE: Card sequence number "5" must appear NM times.

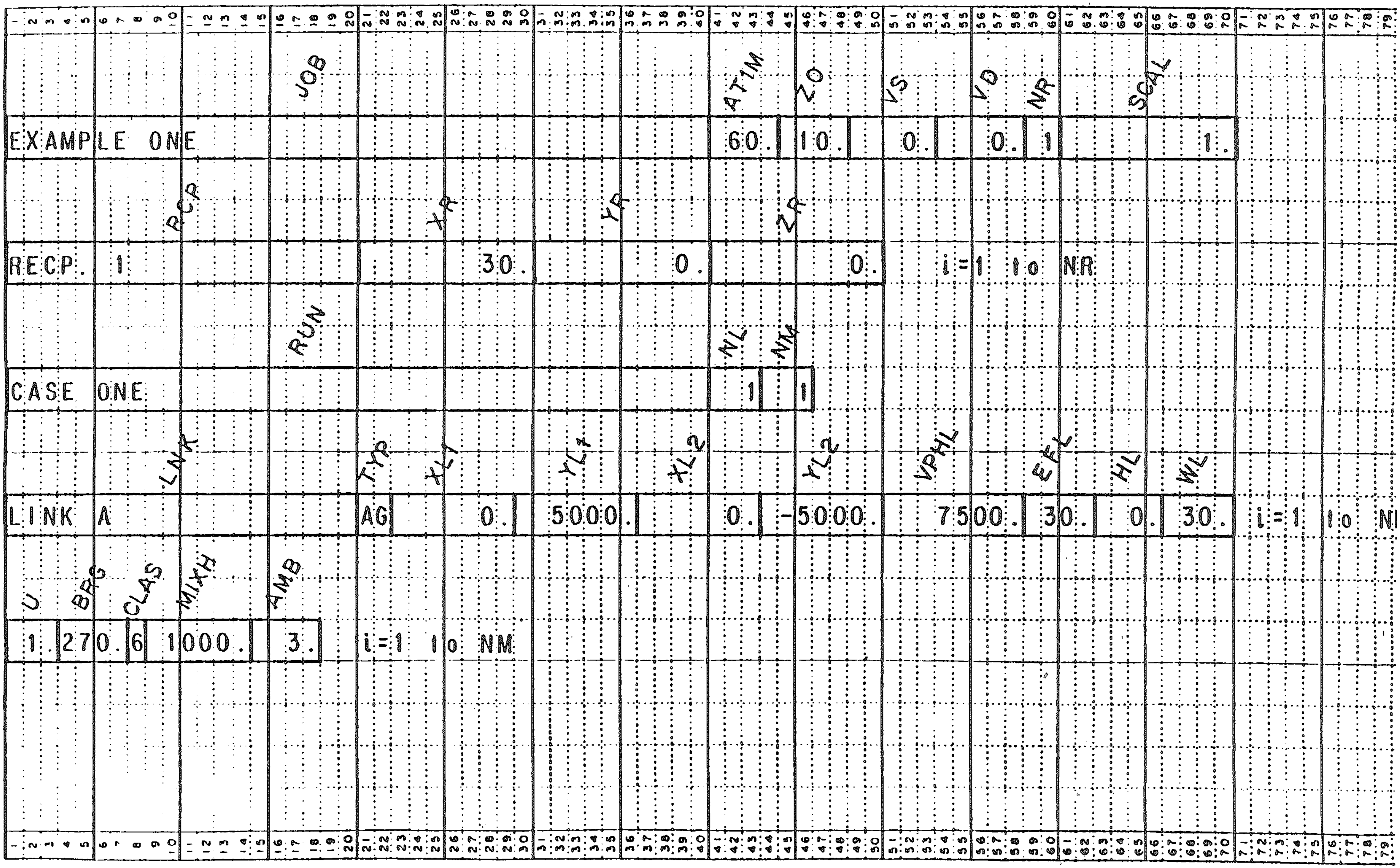
To execute CALINE3 through the statewide Teale Data Center, a data file of the general form shown in Figure 48 must be preceded by the Job Control Language (JCL) shown in Figure 49.

To execute the TENET version of CALINE3, the user must supply the program with a sequential file following the same order of input required for the FORTRAN version. Examples of file input are shown in Section 8.5.

8.4 Output

Output for CALINE3 consists of printed listings containing a summary of all input variables and model results. The input variables are separated into site, link and receptor variables. Model results of CO concentration are given in parts per million (ppm) for each receptor-link combination, and are totaled (including ambient) for each receptor. A separate page of output is generated for each meteorological condition (three page output format is used when NL exceeds 10).

Other inert gaseous pollutants (such as SF_6 tracer) may be run by changing the molecular weight variable (MOWT) within the program to the appropriate value, and modifying the output headings. Similarly, to run the model for particulates, set



DAS-CS 90-062

INPUT DATA CARDS
(FORTRAN VERSION)

FIGURE 48

```
//T_ENVØØL JOB (T_1ØØP,TMMW,T___,___L),DIST__
//*MAIN ORG=RMT__,CLASS=A
//STEP    EXEC   TMENVØØL
      "DATA CARD INPUT"

  JOB CARD COLS.
          4,18,30     ALPHA-NUMERIC DISTRICT CODE (1 THRU B)
          31-33       MSP CODE
          35-38       LABOR COST CODE
          46-47       DISTRICT NUMBER

  //*MAIN CARD COLS.
          16-17       DISTRICT NUMBER
```

DAS-CS 90-062

CALINE3 JOB CONTROL LANGUAGE

FIGURE 49

FPPM=1 and again modify the headings. Results will be in units of $\mu g/m^3$. For both cases, the fixed point format for the output should be modified to handle the range of results expected.

Jobs may be run consecutively, with a new series of pages being started for each job. A brief data edit is executed for each job run. If an error is found, a diagnostic is printed and program execution ends.

8.5 Examples

Four examples have been prepared to assist the user in understanding the model's capabilities. Each example demonstrates several important characteristics of the model. The user should note that the emission factors quoted in these examples are not rigorously derived values.

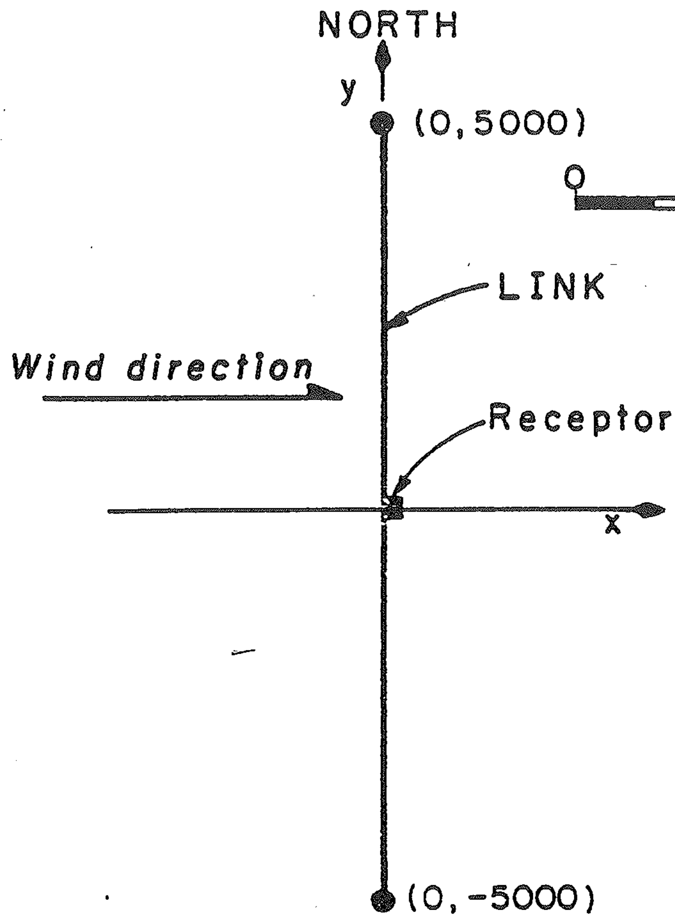
The program required less than 3 seconds of central processing unit (CPU) time on an IBM 370/168 to run all four examples.

8.5.1 Example One - Single Link (see Fig. 50)

Example One is a simple illustration of a single link with one receptor located near the downwind edge of the highway. The purpose of this example is to show how the model handles links which are identical in every way except for their section type and source height.

The link runs in a north-south direction and is 10,000 meters long. The vehicle volume (VPH) is 7500 vehicles/hour, the emission factor (EF) is 30 grams/mile and the mixing zone width (W)

EXAMPLE 1: SINGLE LINK (VARIOUS SECTIONS)



SITE VARIABLES

U = 1 m/s
BRG = 270°
CLAS = 6 (F)
Z0 = 10 cm
ATIM = 60 minutes
VS,VD = 0 cm/s
AMB = 3.0 ppm
MIXH = 1000 m

LINK VARIABLES

VPH = 7500
EF = 30 g/mi
W = 30 m

CASE	TYPE	H(m)
1	AG	0
2	BR	5
3	DP	-5
4	FL	5

RECEPTOR COORDINATES

	X	Y	Z
1.	30	0	1.8

NOTE: Coordinates of Link Endpoints on Diagram (m)

FIGURE 50

is 30 meters. The site variables used are an averaging time (ATIM) of 60 minutes, an atmospheric stability (CLAS) of 6(F), deposition and settling velocities (VD,VS, respectively) of 0 cm/second, an ambient CO concentration (AMB) of 3.0 ppm, and a surface roughness (ZO) of 10 cm. The value for the surface roughness of 10 cm was chosen because the link is assumed to be located in a flat, rural area composed mainly of open fields. The meteorological conditions of wind speed (U) and wind angle (BRG) are 1 m/s and 270 degrees, respectively. The 270 degree wind angle puts the direction of the wind perpendicular to the link (crosswind) and from the west. The receptor is located 30 meters east of the highway centerline at a "nose height" of 1.8 meters.

The file input for all four cases is shown in Exhibit 1. This is in the free format form permitted for the BASIC version. The sequential input of the data is identical for the FORTRAN version, but the field limits shown in Figure 48 must be followed.

For case one, the link is defined as an at-grade type (TYP=AG, H=0). For this configuration, the model calculates a CO concentration of 7.6 ppm (see Exhibit 2 - note that this is the BASIC version output. FORTRAN output is given for Example 4). This includes the 3.0 ppm ambient value shown under site variables.

Cases two and four involve elevated links. Each link is assigned a height of 5 meters above the datum, but for case two the link is defined as a bridge section (TYP=BR), while in case four it is considered a fill section (TYP=FL). The resulting CO concentrations are 6.2 ppm for the "bridge" link and 7.6 ppm for the "fill" link (see Exhibits 3 and 5). The

Exhibit 1

```
'EXAMPLE ONE',60,10,0,0,1,1
'RECP. 1',30,0,1.8
'CASE ONE',1,1
'LINK A',AG,0,-5000,0,5000,7500,30,0,30
1,270,6,1000,3
'EXAMPLE ONE',60,10,0,0,1,1
'RECP. 1',30,0,1.8
'CASE TWO',1,1
'LINK A',BR,0,-5000,0,5000,7500,30,5,30
1,270,6,1000,3
'EXAMPLE ONE',60,10,0,0,1,1
'RECP. 1',30,0,1.8
'CASE THREE',1,1
'LINK A',DP,0,-5000,0,5000,7500,30,-5,30
1,270,6,1000,3
'EXAMPLE ONE',60,10,0,0,1,1
'RECP. 1',30,0,1.8
'CASE FOUR',1,1
'LINK A',FL,0,-5000,0,5000,7500,30,5,30
1,270,6,1000,3
```

Exhibit 2

```
CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
         SEPTEMBER, 1979 VERSION
         PAGE  1

     JOB: EXAMPLE ONE
    FILE: DATA
     RUN: CASE ONE

   I.  SITE VARIABLES

        U =  1.0 M/S        ATIM =  60 MINUTES
      BRG =  270 DEGREES      Z0 =  10 CM
     CLAS =    6 (F)          VS =  .0 CM/S
     MIXH = 1000 M            VD =  .0 CM/S
                             AMB = 3.0 PPM

  II.  LINK VARIABLES

      LINK       *  LINK COORDINATES (M)  *                  EF     H    W
   DESCRIPTION   *  X1     Y1     X2    Y2  * TYPE  VPH  (G/MI) (M)  (M)
-----------------*-----------------------*-------------------------------
 A. LINK A       *   0 -5000     0  5000 *  AG   7500   30.0    0   30

 III.  RECEPTOR LOCATIONS

                 *  COORDINATES (M)
    RECEPTOR     *    X     Y    Z
-----------------*-----------------
  1. RECP. 1     *    30    0  1.8

  IV.  MODEL RESULTS

          *  CO
 RECEPTOR * (PPM)
----------*-------
    1     *  7.6
```

Exhibit 3

```
CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
         SEPTEMBER, 1979 VERSION
         PAGE  2

     JOB: EXAMPLE ONE
    FILE: DATA
     RUN: CASE TWO

   I.  SITE VARIABLES

        U =  1.0 M/S           ATIM =  60 MINUTES
      BRG =  270 DEGREES         ZO =  10 CM
     CLAS =    6 (F)             VS =  .0 CM/S
     MIXH = 1000 M               VD =  .0 CM/S
                                AMB = 3.0 PPM

  II.  LINK VARIABLES

      LINK      *  LINK COORDINATES (M)  *                    EF     H    W
  DESCRIPTION   *  X1    Y1    X2    Y2  *  TYPE   VPH   (G/MI)  (M)  (M)
 ---------------*------------------------*---------------------------------
 A. LINK A      *    0 -5000     0  5000 *   BR    7500   30.0     5   30

 III.  RECEPTOR LOCATIONS

                *  COORDINATES (M)
    RECEPTOR    *    X     Y     Z
 ---------------*------------------
  1. RECP. 1    *   30     0   1.8

  IV.  MODEL RESULTS

          *  CO
 RECEPTOR * (PPM)
 ---------*-------
    1     *  6.2
```

Exhibit 4

CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
SEPTEMBER, 1979 VERSION
PAGE 3

JOB: EXAMPLE ONE
FILE: DATA
RUN: CASE THREE

I. SITE VARIABLES

U =	1.0 M/S	ATIM =	60 MINUTES
BRG =	270 DEGREES	ZO =	10 CM
CLAS =	6 (F)	VS =	.0 CM/S
MIXH =	1000 M	VD =	.0 CM/S
		AMB =	3.0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	LINK COORDINATES (M) X1	Y1	X2	Y2	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	0	-5000	0	5000	DP	7500	30.0	-5	30

III. RECEPTOR LOCATIONS

RECEPTOR	COORDINATES (M) X	Y	Z
1. RECP. 1	30	0	1.8

IV. MODEL RESULTS

RECEPTOR	CO (PPM)
1	5.8

Exhibit 5

```
CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
         SEPTEMBER, 1979 VERSION
         PAGE  4

     JOB: EXAMPLE ONE
    FILE: DATA
     RUN: CASE FOUR

   I.  SITE VARIABLES

        U =  1.0 M/S          ATIM =  60 MINUTES
      BRG =  270 DEGREES        Z0 =  10 CM
     CLAS =    6 (F)            VS =  .0 CM/S
     MIXH = 1000 M              VD =  .0 CM/S
                               AMB = 3.0 PPM

  II.  LINK VARIABLES

      LINK      *  LINK COORDINATES (M)  *                   EF    H   W
  DESCRIPTION   *  X1     Y1     X2    Y2  * TYPE  VPH  (G/MI) (M) (M)
 ---------------*------------------------*---------------------------
 A. LINK A      *    0 -5000      0  5000 *  FL   7500  30.0    5  30

 III.  RECEPTOR LOCATIONS

             *  COORDINATES (M)
    RECEPTOR *    X     Y    Z
 ------------*----------------
  1. RECP. 1 *    30    0  1.8

  IV.  MODEL RESULTS

          *  CO
 RECEPTOR * (PPM)
 ---------*------
     1    *  7.6
```

difference in concentration is due to the method in which contributions from the "bridge" and "fill" links are calculated. For the "bridge" link in case two, it is assumed that the wind is not only blowing over the link, but also underneath it. Thus, the model can use the Gaussian adjustment for source height which assumes a uniform vertical wind distribution both above and below the elevated source. For the "fill" link, the model assumes that the wind streamlines pass over the fill parallel to the ground. Thus, the model treats case four just as if it were an at-grade section.

For case three, the link is designated a depressed section (TYP=DP). All conditions are identical to the previous cases except the source height. CALINE3 increases the pollutant residence time within the mixing zone of a depressed section, thus enhancing initial vertical dispersion. This accounts for the low CO concentration of 5.8 ppm predicted for case three (see Exhibit 4).

8.5.2 Example Two - Rural Curved Alignment (see Fig. 51)

Example two depicts the application of CALINE3 to a rural, curved alignment. Ten connecting links are used to model the highway. The ten links represent three straight sections, a 45° curve, and a 90° curve. The 90° curve is made up of five links, while the 45° curve is made up of only two links. The finer resolution for the 90° curve is needed to obtain an adequate approximation of the highway alignment for the nearby receptors. For the given wind angle, the 45° curve will not contribute significantly to any of the receptors, and thus is only divided up into two links. The input data file is given as Exhibit 6.

EXAMPLE 2: RURAL CURVED ALIGNMENT

NOTE: Coordinates of Link Endpoints on Diagram (m).

RECEPTOR COORDINATES

	X	Y	Z
1.	400	1700	1.8
2.	100	1500	1.8
3.	200	1300	1.8
4.	100	350	1.8

SITE VARIABLES

U = 1.0 m/s
BRG = 45°
CLAS = 6 (F)
ZO = 50 cm
ATIM = 60 minutes
VS,VD = 0 cm/s
AMB = 3.0 ppm
MIXH = 1000 m

LINK VARIABLES

TYPE = AG
VPH = 8500
EF = 30 g/mi
H = 0
W = 28 m

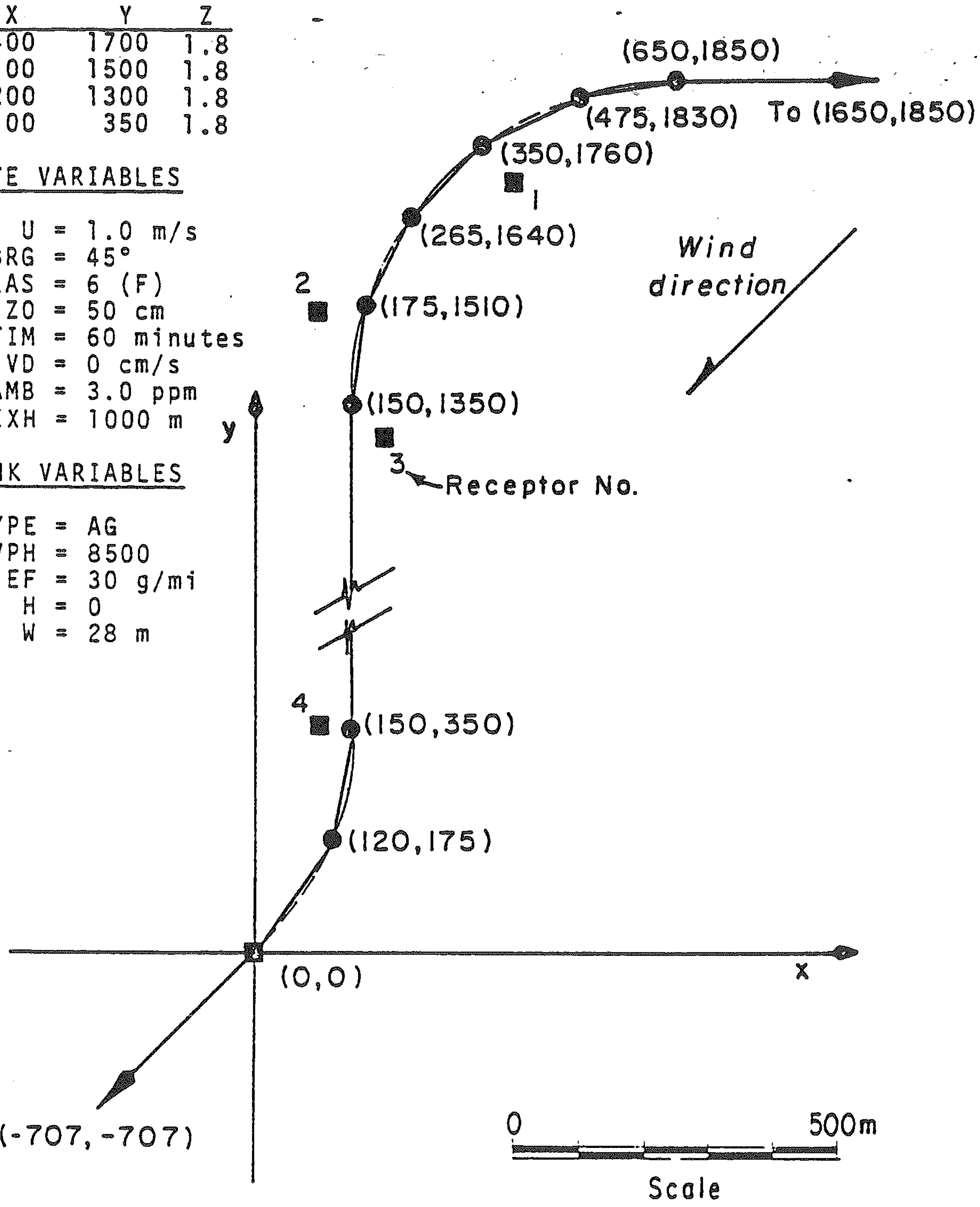


FIGURE 51

Exhibit 6

```
'EXAMPLE TWO',60,50,0,0,4,1
'RECP. 1',400,1700,1.8
'RECP. 2',100,1500,1.8
'RECP. 3',200,1300,1.8
'RECP. 4',100,350,1.8
'RURAL LOCATION: S-CURVE',10,1
'LINK A',AG,-707,-707,0,0,8500,30,0,28
'LINK B',AG,0,0,120,175,8500,30,0,28
'LINK C',AG,120,175,150,350,8500,30,0,28
'LINK D',AG,150,350,150,1350,8500,30,0,28
'LINK E',AG,150,1350,175,1510,8500,30,0,28
'LINK F',AG,175,1510,265,1640,8500,30,0,28
'LINK G',AG,265,1640,350,1760,8500,30,0,28
'LINK H',AG,350,1760,475,1830,8500,30,0,28
'LINK I',AG,475,1830,650,1850,8500,30,0,28
'LINK J',AG,650,1850,1650,1850,8500,30,0,28
1,45,6,1000,3
```

The link conditions placed on this example are a constant vehicle volume of 8500 vehicles per hour and a constant emission factor of 30 grams/mile. Also constant for all ten links are the at-grade source height, and mixing zone width of 28 meters. The two important site variables to note are the ambient concentration (3.0 ppm) and the surface roughness (50 cm). The surface roughness of 50 cm corresponds to assumed rolling, lightly wooded terrain. The model results, which include the ambient concentration, are shown in Exhibit 7. The results appear to be consistent with what would be expected under the wind angle of 45°.

8.5.3 Example Three - Urban Intersection (see Fig. 52)

Example three represents a conventional urban intersection. The user should note that CALINE3 is not a street canyon model, and therefore should not be used to model central business district intersections (i.e., surrounded by buildings of 4 stories or more).

Each street is divided into three links. The intersection links are assigned a much higher emission factor (100 grams/mile) than the approaching links because of the vehicle idling and acceleration that occurs at the intersection. In practice, a modal emissions model would be used to predict a composite emission factor for the driving cycle characteristic of the intersection being modeled. Since the short intersection links are separate from the longer approaching links, the width of the short links can be made wider to include turn lanes. Thus, the multiple link capability of CALINE3 allows the model to take into account differences that exist along an arterial roadway.

Exhibit 7

CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
SEPTEMBER, 1979 VERSION
PAGE 5

JOB: EXAMPLE TWO
FILE: DATA
RUN: RURAL LOCATION: S-CURVE

I. SITE VARIABLES

U = 1.0 M/S
BRG = 45 DEGREES
CLAS = 6 (F)
MIXH = 1000 M

ATIM = 60 MINUTES
ZO = 50 CM
VS = .0 CM/S
VD = .0 CM/S
AMB = 3.0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	*	X1	Y1	X2	Y2	*	TYPE	VPH	EF (G/MI)	H (M)	W (M)
	*	LINK COORDINATES (M)				*					
A. LINK A	*	-707	-707	0	0	*	AG	8500	30.0	0	28
B. LINK B	*	0	0	120	175	*	AG	8500	30.0	0	28
C. LINK C	*	120	175	150	350	*	AG	8500	30.0	0	28
D. LINK D	*	150	350	150	1350	*	AG	8500	30.0	0	28
E. LINK E	*	150	1350	175	1510	*	AG	8500	30.0	0	28
F. LINK F	*	175	1510	265	1640	*	AG	8500	30.0	0	28
G. LINK G	*	265	1640	350	1760	*	AG	8500	30.0	0	28
H. LINK H	*	350	1760	475	1830	*	AG	8500	30.0	0	28
I. LINK I	*	475	1830	650	1850	*	AG	8500	30.0	0	28
J. LINK J	*	650	1850	1650	1850	*	AG	8500	30.0	0	28

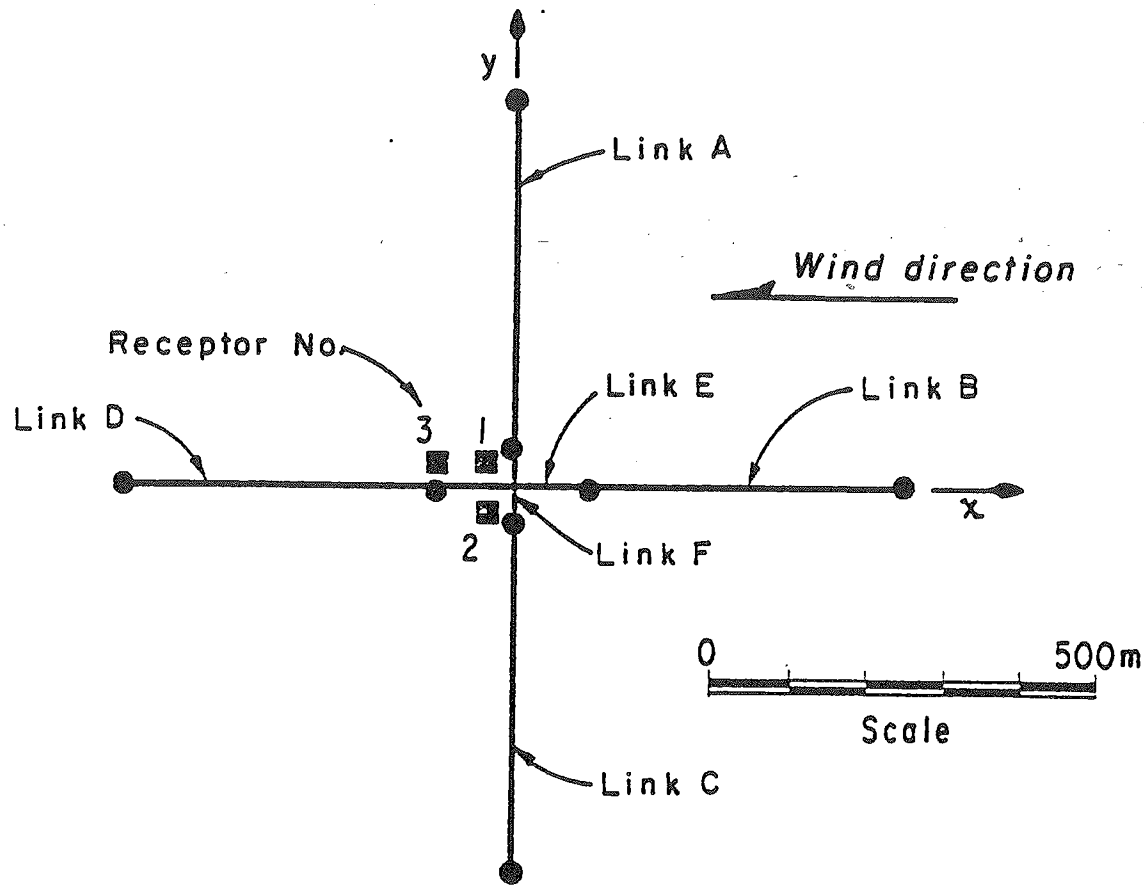
III. RECEPTOR LOCATIONS

RECEPTOR	*	X	Y	Z
	*	COORDINATES (M)		
1. RECP. 1	*	400	1700	1.8
2. RECP. 2	*	100	1500	1.8
3. RECP. 3	*	200	1300	1.8
4. RECP. 4	*	100	350	1.8

IV. MODEL RESULTS

RECEPTOR	*	A	B	C	D	E	F	G	H	I	J	*	TOTAL + AMB (PPM)
	*	CO/LINK (PPM)										*	
1	*	.0	.0	.0	.0	.0	.0	.0	.0	3.1	.0	*	6.1
2	*	.0	.0	.0	.0	.0	1.5	3.7	2.1	.4	.0	*	10.7
3	*	.0	.0	.0	.0	.0	.0	.0	.0	.1	1.3	*	4.4
4	*	.0	.0	.0	4.8	.0	.0	.0	.0	.0	.5	*	8.3

EXAMPLE 3: URBAN INTERSECTION



LINK VARIABLES

	X_1 (m)	Y_1 (m)	X_2 (m)	Y_2 (m)	TYPE	VPH	EF (g/mi)	H (m)	W (m)
LINK A	0	500	0	50	AG	1000	50	0	14
" B	100	0	500	0	"	5000	60	0	26
" C	0	-50	0	-500	"	1000	50	0	14
" D	-500	0	-100	0	"	5000	60	0	26
" E	-100	0	100	0	"	5000	100	0	28
" F	0	50	0	-50	"	1000	100	0	14

RECEPTOR COORDINATES

	X	Y	Z
1.	-30	30	1.8
2.	-30	-30	1.8
3.	-100	30	1.8

SITE VARIABLES

U = 1 m/s ZO = 100 cm
BRG = 90° ATIM = 60 minutes
CLAS = 6 (F) VS,VD = 0 cm/s
MIXH = 100 m AMB = 5.0 ppm

FIGURE 52

The example is set in an urban location so that a surface roughness of 100 cm is used. As in the preceding examples, a worst case 1 hour stability class of F is assumed. Exhibit 8 shows the data input file for Example three. The model results, which include a 5.0 ppm ambient CO concentration, are given in Exhibit 9.

8.5.4 Example Four - Urban Freeway (see Fig. 53)

The final example is designed to show CALINE3's versatility. The example consists of two primary links running east-west, 16 kilometers long. Set in an urban location, the primary links carry traffic volumes of approximately 10,000 vehicles/hour, with an emission factor of 30 grams/mile. An on-ramp link is also included in the example. Because of the constant acceleration occurring at the on-ramp, an emission factor of 150 grams/mile is used. As in Example three, this figure would be based on a modal emissions model. Crossing the primary links are two bridge links with traffic volumes of 4000 and 5000 vehicles/hour.

Twelve receptors are scattered all throughout the study area. By running the model at wind angle increments around the compass, the user can then identify the most critically affected receptors. For this example, 90° increments will be used. In practice, 10° increments are recommended.

With six links, twelve receptors, and four meteorological conditions, CALINE3 is able to handle all situations in a single run (see Exhibit 10 for data input file). The FORTRAN output shown in Exhibits 11-14 contains all the values of the input variables, and model results which include a link by link breakdown for each receptor concentration.

Exhibit 8

```
'EXAMPLE THREE',60,100,0,0,3,1
'RECP. 1',-30,30,1.8
'RECP. 2',-30,-30,1.8
'RECP. 3',-100,30,1.8
'URBAN LOCATION: INTERSECTION',6,1
'LINK A',AG,0,500,0,50,1000,50,0,14
'LINK B',AG,100,0,500,0,5000,60,0,26
'LINK C',AG,0,-50,0,-500,1000,50,0,14
'LINK D',AG,-500,0,-100,0,5000,60,0,26
'LINK E',AG,-100,0,100,0,5000,100,0,28
'LINK F',AG,0,50,0,-50,1000,100,0,14
1,90,6,100,5
```

Exhibit 9

CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL
SEPTEMBER, 1979 VERSION
PAGE 6

JOB: EXAMPLE THREE
FILE: DATA
RUN: URBAN LOCATION: INTERSECTION

I. SITE VARIABLES

U = 1.0 M/S
BRG = 90 DEGREES
CLAS = 6 (F)
MIXH = 100 M

ATIM = 60 MINUTES
ZO = 100 CM
VS = .0 CM/S
VD = .0 CM/S
AMB = 5.0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	*	X1	Y1	X2	Y2	*	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	*	0	500	0	50	*	AG	1000	50.0	0	14
B. LINK B	*	100	0	500	0	*	AG	5000	60.0	0	26
C. LINK C	*	0	-50	0	-500	*	AG	1000	50.0	0	14
D. LINK D	*	-500	0	-100	0	*	AG	5000	60.0	0	26
E. LINK E	*	-100	0	100	0	*	AG	5000	100.0	0	28
F. LINK F	*	0	50	0	-50	*	AG	1000	100.0	0	14

(X1, Y1, X2, Y2: LINK COORDINATES (M))

III. RECEPTOR LOCATIONS

RECEPTOR	*	X	Y	Z
1. RECP. 1	*	-30	30	1.8
2. RECP. 2	*	-30	-30	1.8
3. RECP. 3	*	-100	30	1.8

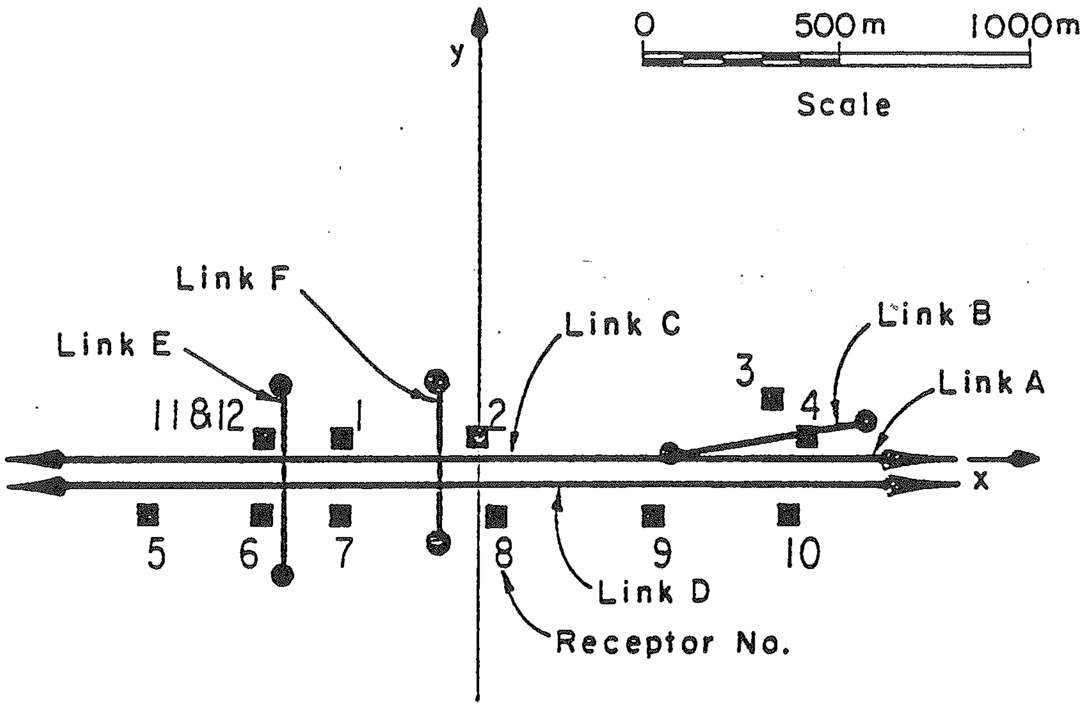
(X, Y, Z: COORDINATES (M))

IV. MODEL RESULTS

RECEPTOR	*	A	B	C	D	E	F	*	TOTAL + AMB (PPM)
1	*	.0	5.4	.0	.0	.8	1.9	*	13.1
2	*	.0	5.4	.0	.0	.8	1.9	*	13.1
3	*	.0	5.1	.0	.0	2.4	1.0	*	13.5

(A–F: CO/LINK (PPM))

EXAMPLE 4: URBAN FREEWAY



LINK VARIABLES

	X_1 (m)	Y_1 (m)	X_2 (m)	Y_2 (m)	TYPE	VPH	EF (g/mi)	H (m)	W (m)
LINK A	500	0	3000	0	AG	9700	30	0	23
" B	500	0	1000	100	DP	1200	150	-2.0	13
" C	-3000	0	500	0	AG	10900	30	0	23
" D	-3000	-75	3000	-75	AG	9300	30	0	23
" E	-500	200	-500	-300	BR	4000	50	6.1	27
" F	-100	200	-100	-200	BR	5000	50	6.1	27

SITE VARIABLES

U = 1 m/s
BRG = 0°, 90°, 180°, 270°
CLAS = 6 (F)
Z0 = 100 cm
ATIM = 60 minutes
VS,VD = 0 cm/s
AMB = 12.0, 7.0, 5.0, 6.7
MIXH = 1000 m

RECEPTOR COORDINATES

(See Output)

FIGURE 53

Exhibit 10

```
'EXAMPLE FOUR',60,100,0,0,12,1
'RECP. 1',-350,30,1.8
'RECP. 2',0,30,1.8
'RECP. 3',750,100,1.8
'RECP. 4',850,30,1.8
'RECP. 5',-850,-100,1.8
'RECP. 6',-550,-100,1.8
'RECP. 7',-350,-100,1.8
'RECP. 8',50,-100,1.8
'RECP. 9',450,-100,1.8
'RECP. 10',800,-100,1.8
'RECP. 11',-550,25,1.8
'RECP. 12',-550,25,6.1
'URBAN LOCATION: MULTIPLE LINKS W/ ON-RAMP AND OVERPASSES',6,4
'LINK A',AG,500,0,3000,0,9700,30,0,23
'LINK B',DP,500,0,1000,100,1200,150,-2,0,13
'LINK C',AG,-3000,0,500,0,10900,30,0,23
'LINK D',AG,-3000,-75,3000,-75,9300,30,0,23
'LINK E',BR,-500,200,-500,-300,4000,50,6.1,27
'LINK F',BR,-100,200,-100,-200,5000,50,6.1,27
1,0,6,1000,12
1,90,6,1000,7
1,180,6,1000,5
1,270,6,1000,6.7
```

JOB: EXAMPLE FOUR RUN: URBAN LOCATION: MULTIPLE LINKS, ETC.

I. SITE VARIABLES

U = 1.0 M/S CLAS = 6 (F) VS = 0.0 CM/S ATIM = 60. MINUTES MIXH = 1000. M
BRG = 0. DEGREES Z0 = 100. CM VD = 0.0 CM/S AMB = 12.0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	LINK COORDINATES (M) X1	Y1	X2	Y2	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	500.	0.	3000.	0.	2500.	90.	AG	9700.	30.0	0.0	23.0
B. LINK B	500.	0.	1000.	100.	510.	79.	DP	1200.	150.0	-2.0	13.0
C. LINK C	-3000.	0.	500.	0.	3500.	90.	AG	10900.	30.0	0.0	23.0
D. LINK D	-3000.	-75.	3000.	-75.	6000.	90.	AG	9300.	30.0	0.0	23.0
E. LINK E	-500.	200.	-500.	-300.	500.	180.	BR	4000.	50.0	6.1	27.0
F. LINK F	-100.	200.	-100.	-200.	400.	180.	BR	5000.	50.0	6.1	27.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	COORDINATES (M) X	Y	Z	TOTAL + AMB (PPM)	CO/LINK (PPM) A	B	C	D	E	F
1. RECP. 1	-350.	30.	1.8	12.0	0.0	0.0	0.0	0.0	0.0	0.0
2. RECP. 2	0.	30.	1.8	12.0	0.0	0.0	0.0	0.0	0.0	0.0
3. RECP. 3	750.	100.	1.8	12.0	0.0	0.0	0.0	0.0	0.0	0.0
4. RECP. 4	850.	30.	1.8	14.8	0.0	2.8	0.0	0.0	0.0	0.0
5. RECP. 5	-850.	-100.	1.8	21.7	0.0	0.0	3.6	6.1	0.0	0.0
6. RECP. 6	-550.	-100.	1.8	22.0	0.0	0.0	3.6	6.1	0.3	0.0
7. RECP. 7	-350.	-100.	1.8	21.7	0.0	0.0	3.6	6.1	0.0	0.0
8. RECP. 8	50.	-100.	1.8	21.7	0.0	0.0	3.6	6.1	0.0	0.0
9. RECP. 9	450.	-100.	1.8	21.7	0.0	0.0	3.6	6.1	0.0	0.0
10. RECP. 10	800.	-100.	1.8	22.7	3.2	1.4	0.0	6.1	0.0	0.0
11. RECP. 11	-550.	25.	1.8	12.0	0.0	0.0	0.0	0.0	0.0	0.0
12. RECP. 12	-550.	25.	6.1	12.0	0.0	0.0	0.0	0.0	0.0	0.0

EXHIBIT 11

CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL - SEPTEMBER, 1979 VERSION PAGE 8

JOB: EXAMPLE FOUR

RUN: URBAN LOCATION: MULTIPLE LINKS, ETC.

I. SITE VARIABLES

U = 1.0 M/S　　CLAS = 6 (F)　　VS = 0.0 CM/S　　ATIM = 60. MINUTES　　MIXH = 1000. M
BRG = 90. DEGREES　　Z0 = 100. CM　　VD = 0.0 CM/S　　AMB = 7.0 PPM

II. LINK VARIABLES

LINK DESCRIPTION	LINK COORDINATES (M) X1	Y1	X2	Y2	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	500.	0.	3000.	0.	2500.	90.	AG	9700.	30.0	0.0	23.0
B. LINK B	500.	0.	1000.	100.	510.	79.	DP	1200.	150.0	-2.0	13.0
C. LINK C	-3000.	0.	500.	0.	3500.	90.	AG	10900.	30.0	0.0	23.0
D. LINK D	-3000.	-75.	3000.	-75.	6000.	90.	AG	9300.	30.0	0.0	23.0
E. LINK E	-500.	200.	-500.	-300.	500.	180.	BR	4000.	50.0	6.1	27.0
F. LINK F	-100.	200.	-100.	-200.	400.	180.	BR	5000.	50.0	6.1	27.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	COORDINATES (M) X	Y	Z	TOTAL + AMB (PPM)	CO/LINK (PPM) A	B	C	D	E	F
1. RECP. 1	-350.	30.	1.8	28.4	5.7	1.3	8.9	3.9	0.0	1.6
2. RECP. 2	0.	30.	1.8	26.6	8.0	2.1	5.9	3.6	0.0	0.0
3. RECP. 3	750.	100.	1.8	13.7	3.2	2.6	0.0	0.9	0.0	0.0
4. RECP. 4	850.	30.	1.8	21.7	12.0	0.0	0.0	2.7	0.0	0.0
5. RECP. 5	-850.	-100.	1.8	29.6	3.1	0.4	1.8	15.3	1.1	0.9
6. RECP. 6	-550.	-100.	1.8	30.5	3.5	0.3	1.1	15.1	2.3	1.2
7. RECP. 7	-350.	-100.	1.8	28.2	3.7	0.3	0.7	14.9	0.0	1.6
8. RECP. 8	50.	-100.	1.8	25.5	3.9	0.1	0.0	14.5	0.0	0.0
9. RECP. 9	450.	-100.	1.8	24.5	3.5	0.0	0.0	14.0	0.0	0.0
10. RECP. 10	800.	-100.	1.8	23.6	3.1	0.0	0.0	13.5	0.0	0.0
11. RECP. 11	-550.	25.	1.8	33.0	4.9	1.0	12.3	4.3	2.3	1.2
12. RECP. 12	-550.	25.	6.1	32.0	4.8	1.0	11.7	4.3	2.0	1.2

EXHIBIT 12

JOB: EXAMPLE FOUR RUN: URBAN LOCATION: MULTIPLE LINKS, ETC.

I. SITE VARIABLES

U = 1.0 M/S	CLAS = 6 (F)	VS = 0.0 CM/S	ATIM = 60. MINUTES	MIXH = 1000. M
BRG = 180. DEGREES	Z0 = 100. CM	VD = 0.0 CM/S	AMB = 5.0 PPM	

II. LINK VARIABLES

LINK DESCRIPTION	LINK COORDINATES (M) X1	Y1	X2	Y2	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	500.	0.	3000.	0.	2500.	90.	AG	9700.	30.0	0.0	23.0
B. LINK B	500.	0.	1000.	100.	510.	79.	DP	1200.	150.0	-2.0	13.0
C. LINK C	-3000.	0.	500.	0.	3500.	90.	AG	10900.	30.0	0.0	23.0
D. LINK D	-3000.	-75.	3000.	-75.	6000.	90.	AG	9300.	30.0	0.0	23.0
E. LINK E	-500.	200.	-500.	-300.	500.	180.	BR	4000.	50.0	6.1	27.0
F. LINK F	-100.	200.	-100.	-200.	400.	180.	BR	5000.	50.0	6.1	27.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	COORDINATES (M) X	Y	Z	TOTAL + AMB (PPM)	CO/LINK (PPM) A	B	C	D	E	F
1. RECP. 1	-350.	30.	1.8	14.5	0.0	0.0	6.5	3.0	0.0	0.0
2. RECP. 2	0.	30.	1.8	14.5	0.0	0.0	6.5	3.0	0.0	0.0
3. RECP. 3	750.	100.	1.8	13.0	3.2	2.5	0.0	2.3	0.0	0.0
4. RECP. 4	850.	30.	1.8	13.8	5.8	0.0	0.0	3.0	0.0	0.0
5. RECP. 5	-850.	-100.	1.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0
6. RECP. 6	-550.	-100.	1.8	5.1	0.0	0.0	0.0	0.0	0.1	0.0
7. RECP. 7	-350.	-100.	1.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0
8. RECP. 8	50.	-100.	1.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0
9. RECP. 9	450.	-100.	1.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0
10. RECP. 10	800.	-100.	1.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0
11. RECP. 11	-550.	25.	1.8	15.6	0.0	0.0	7.1	3.1	0.4	0.0
12. RECP. 12	-550.	25.	6.1	12.0	0.0	0.0	3.9	2.7	0.4	0.0

EXHIBIT 13

JOB: EXAMPLE FOUR RUN: URBAN LOCATION: MULTIPLE LINKS, ETC.

I. SITE VARIABLES

U = 1.0 M/S	CLAS = 6 (F)	VS = 0.0 CM/S	ATIM = 60. MINUTES	MIXH = 1000. M
BRG = 270. DEGREES	ZO = 100. CM	VD = 0.0 CM/S	AMB = 6.7 PPM	

II. LINK VARIABLES

LINK DESCRIPTION	LINK COORDINATES (M) X1	Y1	X2	Y2	LINK LENGTH (M)	LINK BRG (DEG)	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. LINK A	500.	0.	3000.	0.	2500.	90.	AG	9700.	30.0	0.0	23.0
B. LINK B	500.	0.	1000.	100.	510.	79.	DP	1200.	150.0	-2.0	13.0
C. LINK C	-3000.	0.	500.	0.	3500.	90.	AG	10900.	30.0	0.0	23.0
D. LINK D	-3000.	-75.	3000.	-75.	6000.	90.	AG	9300.	30.0	0.0	23.0
E. LINK E	-500.	200.	-500.	-300.	500.	180.	BR	4000.	50.0	6.1	27.0
F. LINK F	-100.	200.	-100.	-200.	400.	180.	BR	5000.	50.0	6.1	27.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS

RECEPTOR	COORDINATES (M) X	Y	Z	TOTAL + AMB (PPM)	CO/LINK (PPM) A	B	C	D	E	F
1. RECP. 1	-350.	30.	1.8	25.8	0.0	0.0	14.3	3.2	1.6	0.0
2. RECP. 2	0.	30.	1.8	28.4	0.0	0.0	14.8	3.6	0.9	2.4
3. RECP. 3	750.	100.	1.8	15.2	0.0	0.0	5.2	2.0	0.5	0.8
4. RECP. 4	850.	30.	1.8	32.8	3.4	5.2	11.9	4.3	0.5	0.8
5. RECP. 5	-850.	-100.	1.8	23.5	0.0	0.0	3.4	13.4	0.0	0.0
6. RECP. 6	-550.	-100.	1.8	24.4	0.0	0.0	3.8	13.9	0.0	0.0
7. RECP. 7	-350.	-100.	1.8	26.6	0.0	0.0	4.1	14.2	1.6	0.0
8. RECP. 8	50.	-100.	1.8	28.9	0.0	0.0	4.6	14.7	0.9	2.0
9. RECP. 9	450.	-100.	1.8	28.6	0.0	0.0	5.0	15.1	0.7	1.1
10. RECP. 10	800.	-100.	1.8	28.7	0.0	0.0	5.3	15.3	0.6	0.8
11. RECP. 11	-550.	25.	1.8	26.3	0.0	0.0	16.3	3.3	0.0	0.0
12. RECP. 12	-550.	25.	6.1	25.6	0.0	0.0	15.7	3.2	0.0	0.0

EXHIBIT 14

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APPENDIX A - CALINE3

(BASIC VERSION)

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100 REM **********  C A L I N E 3  **********

       SEPTEMBER, 1979 VERSION
       DEVELOPER: PAUL BENSON (916) 739-2459
                                ATSS 497-2459
110 REM     AGENCY: CALTRANS
                    TRANSPORTATION LAB
                    5900 FOLSOM BLVD.
                    SACRAMENTO, CA  95819


120 REM *****  PROGRAM DESCRIPTION  *****

       CALINE3 IS THE 3RD GENERATION GAUSSIAN LINE SOURCE AIR
       QUALITY MODEL DEVELOPED BY CALTRANS.  ITS PURPOSE IS TO
       PREDICT POLLUTANT CONCENTRATIONS NEAR TRANSPORTATION
130 REM FACILITIES (MICROSCALE REGION).  THE PRESENT VERSION
       CAN PROCESS UP TO 20 LINKS AND 20 RECEPTORS FOR AN
       UNLIMITED NUMBER OF METEOROLOGICAL CONDITIONS.


140 REM *****  INITIALIZATION OF CONSTANTS  *****

150 MOWT=28  ! MOLECULAR WEIGHT CO
160 FPPM=0.0245/MOWT    ! FACTOR MICRO-GRAMS/METER^3 TO PPM
170 DOUBLE A,B,L,D,XPRI,YPRI,APRI,BPRI,LPRI,DPRI
180 DOUBLE HYP,SIDE,FAC2,PD,XD,YD
190 DIM C(20,20),XR(20),YR(20),ZR(20),XL1(20),XL2(20),YL1(20),
      YL2(20),VPHL(20),EFL(20),HL(20),WL(20),AZ(6),AY1(6),
      AY2(6),Y(6),WT(5)
200 DOUBLE LL(20),INTG(6)
210 DIM STB$(6),COD$(20),LNK$(20),RCP$(20),TYP$(20)
220 MAT READ AZ,AY1,AY2,WT
230 DATA 1112 566 353 219 124 56   ! SIGMA Z (M) AT 10 KM
240 DATA .46 .29 .18 .11 .087 .057   ! SIGMA Y (M) AT 1 M
250 DATA 1831 1155 717 438 346 227   ! SIGMA Y (M) AT 10 KM
260 DATA .25 .75 1 .75 .25   ! SOURCE STRENGTH WEIGHTING MATRIX
270 DREF=LOG(10000)
280 MAT READ STB$,COD$
290 DATA A,B,C,D,E,F,
300 DATA A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,


310 REM *****  HEADING  *****

320 PRINT '       * * *  PROGRAM '5;ENV;CALINE3' 9/1/79':
      ' VERSION  * * *'
330 PRINT
340 PRINT IN FORM '// 'INPUT DATAFILE NAME'':
350 INPUT FIL$
360 OPEN FIL$,1,INPUT,OLD
370 ON ENDFILE(1) GOTO 3640
380 PRINT
390 PRINT 'ADVANCE PRINT HEAD TO NEXT PERFORATION THEN ':
    'CARRIAGE RETURN':
400 INPUT IN FORM '255%':JUNK
410 PGCT=1   ! PAGE COUNTER
```

```
420 REM ***** DATA INPUT AND EDIT  *****

430 INPUT FROM 1:JOB$,ATIM,ZO,VS,VD,NR,SCAL
440 REM        ATIM = AVERAGING TIME (MINUTES)
                 ZO = ROUGHNESS (CM)
                 VS = SETTLING VELOCITY (CM/S)
                 VD = DEPOSITION VELOCITY (CM/S)
                 NR = NUMBER OF RECEPTORS
450 REM        SCAL = COORDINATE SCALE FACTOR
                      (TO CONVERT TO METERS)
460 VS=VS/100   ! CONVERT CM/S TO M/S
470 VD=VD/100
480 V1=VD-VS/2
490 FOR I=1 TO NR
500 INPUT FROM 1:RCP$(I),XR(I),YR(I),ZR(I)
510 REM  XR,YR,ZR = RECEPTOR COORDINATES
520 XR(I)=SCAL*XR(I)
530 YR(I)=SCAL*YR(I)
540 ZR(I)=SCAL*ZR(I)
550 NEXT I
560 INPUT FROM 1:RUN$,NL,NM
570 REM          NL = NUMBER OF LINKS
                 NM = NUMBER OF MET CONDITIONS
580 FOR I=1 TO NL
590 INPUT FROM 1:LNK$(I),TYP$(I),XL1(I),YL1(I),XL2(I),YL2(I),VPHL(I),
                  EFL(I),HL(I),WL(I)
600 REM        TYP$ = HIGHWAY TYPE
                        AG: AT-GRADE
                        DP: DEPRESSED (CUT)
                        FL: FILL
                        BR: BRIDGE
610 REM   XL1,ETC. = LINK ENDPOINT COORDINATES
              VPHL = TRAFFIC VOLUME (VEHICLES/HR)
               EFL = EMISSION FACTOR (GMS/MI) .
                HL = SOURCE HEIGHT (M)
                WL = MIXING ZONE WIDTH (M)
620 XL1(I)=SCAL*XL1(I)
630 YL1(I)=SCAL*YL1(I)
640 XL2(I)=SCAL*XL2(I), HL(I)=SCAL*HL(I)
650 YL2(I)=SCAL*YL2(I), WL(I)=SCAL*WL(I)
660 LL(I)=SQRT((XL1(I)-XL2(I))^2+(YL1(I)-YL2(I))^2)  ! LINK LENGTH
670 IF LL(I)<WL(I) THEN 680 ELSE 700
680 PRINT 'LINK LENGTH MUST BE GREATER THAN OR EQUAL TO':
        ' LINK WIDTH.'
690 END
700 IF ABS(HL(I))>10 THEN 710 ELSE 730
710 PRINT 'SOURCE MUST BE WITHIN 10 METERS OF DATUM'
720 END
730 NEXT I


740 REM *****  MET LOOP  *****

750 FOR IM=1 TO NM
760 INPUT FROM 1:U,BRG,CLAS,MIXH,AMB
770 REM            U = WIND SPEED (M/S)
                 BRG = WIND DIRECTION (DEGREES)
                CLAS = STABILITY CLASS (A-F)
                MIXH = MIXING HEIGHT (M)
                 AMB = AMBIENT CONCENTRATION (PPM)
```

```
780 BRG1=BRG
790 BRG=BRG+180    ! CONVERT WIND VECTOR TO CONVENTIONAL VECTOR
800 IF BRG>=360 THEN BRG=BRG-360
810 XVEC=COS(RAD(450-BRG))    ! VIRTUAL DISPLACEMENT VECTORS
820 YVEC=SIN(RAD(450-BRG))
830 REM  CORRECTIONS FOR AVERAGING TIME AND SURFACE ROUGHNESS
840 AFAC=(ATIM/3)^.2
850 SY1=LOG(AY1(CLAS)*((Z0/3)^.2)*AFAC)    ! LOG(SIGMA Y) AT 1 M
860 SY10=LOG(AY2(CLAS)*((Z0/3)^.07)*AFAC)    ! LOG(SIGMA Y) AT 10 KM
870 SZ10=LOG(AZ(CLAS)*((Z0/10)^.07)*AFAC)    ! LOG(SIGMA Z) AT 10 KM
880 REM  SIGMA Y POWER CURVE
890 PY1=EXP(SY1)
900 PY2=(SY10-SY1)/DREF
910 MAT C=ZER    ! ZERO CONCENTRATION MATRIX


920 REM *****  LINK LOOP  *****

930 FOR IL=1 TO NL
940 VPH=VPHL(IL)
950 EF=EFL(IL)
960 IF TYP$(IL)='DP' OR TYP$(IL)='FL' THEN H=0 ELSE H=HL(IL)
970 W=WL(IL)
980 GOSUB 2210    ! TO LINK COMPUTATIONS


990 REM *****  RECEPTOR LOOP  *****

1000 FOR IR=1 TO NR
1010 A=(XR(IR)-XL1(IL))^2+(YR(IR)-YL1(IL))^2
1020 B=(XR(IR)-XL2(IL))^2+(YR(IR)-YL2(IL))^2
1030 L=(B-A-LL(IL)^2)/(2*LL(IL))    ! OFFSET LENGTH
1040 IF A>L^2 THEN D=SQRT(A-L^2) ELSE D=0    ! RECEPTOR DISTANCE
1050 UWL=LL(IL)+L    ! UPWIND LENGTH
1060 DWL=L           ! DOWNWIND LENGTH
1070 REM  VIRTUAL DISPLACEMENT CALCULATIONS
1080 XPRI=XR(IR)+D*XVEC
1090 YPRI=YR(IR)+D*YVEC
1100 APRI=(XPRI-XL1(IL))^2+(YPRI-YL1(IL))^2
1110 BPRI=(XPRI-XL2(IL))^2+(YPRI-YL2(IL))^2
1120 LPRI=(BPRI-APRI-LL(IL)^2)/(2*LL(IL))
1130 IF APRI>LPRI^2 THEN DPRI=SQRT(APRI-LPRI^2) ELSE DPRI=0
1140 IF DPRI<D THEN D=-D
1150 IF LPRI<L THEN TEMP=UWL ELSE 1180
1160 UWL=-DWL
1170 DWL=-TEMP
1180 IF TYP$(IL)='AG' OR TYP$(IL)='BR' THEN 1220
1190 IF ABS(D)>=W2+2*ABS(HL(IL)) THEN 1220    ! 2:1 SLOPE ASSUMED
1200 IF ABS(D)<=W2 THEN Z=ZR(IR)-HL(IL) ELSE
                        Z=ZR(IR)-HL(IL)*(1-(ABS(D)-W2)/(2*ABS(HL(IL))))
1210 GOTO 1230
1220 Z=ZR(IR)
1230 GOSUB 2600
1240 NEXT IR,IL
1250 MAT C=(FPPM)*C


1260 REM *****  OUTPUT  *****

1270 LINESIZE 80
```

```
1280 LNCT=40+NL+NR+MIN(NR,10)   ! LINE COUNT
1290 IF NL>1 THEN LNCT=LNCT+1
1300 IF NL>10 THEN LNCT=LNCT+NR+6
1310 IF LNCT>66 THEN LNCT=LNCT-66
1320 IF PGCT=1 THEN PRINT IN FORM "3/": ELSE
     PRINT IN FORM "4/":
1330 PRINT ".     CALINE3: CALIFORNIA LINE SOURCE DISPERSION MODEL"
1340 PRINT "                  SEPTEMBER, 1979 VERSION"
1350 PRINT IN FORM "14B 'PAGE ' 2% // 9B 'JOB: ' 60% / 8B 'FILE: '
               8% / 9B 'RUN: ' 60% ///":PGCT,JOB$,FIL$,RUN$
1360 PRINT TAB(8):"I.  SITE VARIABLES"
1370 PRINT IN FORM "/ 12B 'U =' 3%.% ' M/S' 7B 'ATIM =' 4%
     ' MINUTES' / 10B 'BRG =' 5% ' DEGREES' 5B 'Z0 =' 4% ' CM' /
     9B 'CLAS =' 4B % ' (' % ')' 9B 'VS =' 2%.% ' CM/S' /":
     U,ATIM,BRG1,Z0,CLAS,STB$(CLAS),100*VS
1380 PRINT IN FORM "9B 'MIXH =' 5% ' M' 11B 'VD =' 2%.%
     ' CM/S' / 32B 'AMB =' 2%.% ' PPM' //":MIXH,100*VD,AMB
1390 PRINT TAB(7):"II.  LINK VARIABLES"
1400 PRINT
1410 PRINT TAB(12):"LINK     *":TAB(24):"LINK COORDINATES (M)   *":
         TAB(61):"EF    H   W"
1420 PRINT TAB(8):"DESCRIPTION  *  X1     Y1     X2     Y2  * TYPE":
         "  VPH  (G/MI) (M) (M)"
1430 PRINT IN FORM "5B 15('-') '*' 24('-') '*' 26('-') /":
1440 FOR I=1 TO NL
1450 PRINT IN FORM "5B % '. ' 11% B '*' 5% 3(6%) ' *' 2B 2% 7% 4%.%
     2(4%) /":COD$(I),LNK$(I),XL1(I),YL1(I),XL2(I),YL2(I),TYP$(I),
     VPHL(I),EFL(I),HL(I),WL(I)
1460 NEXT I
1470 PRINT IN FORM "//":
1480 PRINT TAB(6):"III.  RECEPTOR LOCATIONS"
1490 PRINT
1500 PRINT IN FORM "19B '*  COORDINATES (M)'":
1510 IF NR<=10 THEN PRINT IN FORM "/": ELSE PRINT IN FORM
     "' *' 15B '*  COORDINATES (M)' /":
1520 IF NR<=10 THEN PRINT TAB(10):"RECEPTOR  *     X     Y     Z"
     ELSE PRINT TAB(10):"RECEPTOR  *     X     Y     Z   *":
     TAB(45):"RECEPTOR  *     X     Y     Z"
1530 IF NR<=10 THEN PRINT IN FORM "5B 14('-') '*' 18('-') /": ELSE
     PRINT IN FORM "5B 14('-') '*' 18('-') '*' 15('-')
     '*' 18('-') /":
1540 FOR I=1 TO NR
1550 IF I>10 THEN 1610
1560 IF NR<=10 OR I+10>NR THEN 1590
1570 PRINT IN FORM "7% '. ' 9% ' * ' 2(5%) 3%.% '   *' 3%
     '. ' 9% ' * ' 2(5%) 3%.% /":I,RCP$(I),XR(I),YR(I),ZR(I),
     I+10,RCP$(I+10),XR(I+10),YR(I+10),ZR(I+10)
1580 GOTO 1600
1590 PRINT IN FORM "7% '. ' 9% ' * ' 2(5%) 3%.% /":I,RCP$(I),XR(I),
     YR(I),ZR(I)
1600 NEXT I
1610 PRINT IN FORM "//":
1620 PRINT TAB(7):"IV.  MODEL RESULTS"
1630 PRINT
1640 IF NL>1 THEN 1690
1650 PRINT TAB(15):"*  CO"
1660 PRINT TAB(6):"RECEPTOR * (PPM)"
1670 PRINT IN FORM "5B 9('-') '*' 7('-') /":
1680 GOTO 1810
1690 NLR=MIN(NL,10)
```

```
1700 PRINT TAB(15):"*":TAB(ROUND(17+(NLR*5-7)/2)):"CO/LINK":
     TAB(17+NLR*5):" * TOTAL"
1710 PRINT TAB(15):"*":TAB(ROUND(17+(NLR*5-5)/2)):"(PPM)":
     TAB(17+NLR*5):" * + AMB"
1720 PRINT IN FORM "5B 'RECEPTOR * '":
1730 FOR I=1 TO NLR
1740 PRINT IN FORM "2B 3%":COD$(I)
1750 NEXT I
1760 PRINT IN FORM "B '* (PPM)' / 5B 9('-') '*'":
1770 FOR I=1 TO 5*NLR+2
1780 PRINT IN FORM "'-'":
1790 NEXT I
1800 PRINT IN FORM "'*' 6('-') /":
1810 FOR I=1 TO NR
1820 PRINT IN FORM "10% 4B '*'":I
1830 IF NL<2 THEN 1940
1840 CSUM=0
1850 FOR J=1 TO NL
1860 CSUM=CSUM+ROUND(10*C(J,I))/10
1870 NEXT J
1880 CSUM=CSUM+AMB   ! ADDITION OF AMBIENT
1890 FOR J=1 TO NLR
1900 PRINT IN FORM "3%.%":C(J,I)
1910 NEXT J
1920 PRINT IN FORM "'   *' 3%.% /":CSUM
1930 GOTO 1950
1940 PRINT IN FORM "3%.% /":C(1,I)+AMB
1950 NEXT I
1960 IF NL<=10 THEN 2150
1970 NLR=NL-10
1980 PRINT IN FORM "//":
1990 PRINT TAB(15):"*":TAB(ROUND(17+(NLR*5-7)/2)):"CO/LINK"
2000 PRINT TAB(15):"*":TAB(ROUND(17+(NLR*5-5)/2)):"(PPM)"
2010 PRINT IN FORM "5B 'RECEPTOR *'":
2020 FOR I=11 TO NL
2030 PRINT IN FORM "2B 3%":COD$(I)
2040 NEXT I
2050 PRINT IN FORM "/ 5B 9('-') '*'":
2060 DO 1770:1790
2070 PRINT IN FORM "/":
2080 FOR I=1 TO NR
2090 PRINT IN FORM "10% 4B '*'":I
2100 FOR J=11 TO NL
2110 PRINT IN FORM "3%.%":C(J,I)
2120 NEXT J
2130 PRINT IN FORM "/":
2140 NEXT I
2150 FOR LN=1 TO 66-LNCT   ! PAGING
2160 PRINT CHAR(10):
2170 NEXT LN
2180 PGCT=PGCT+1
2190 NEXT IM
2200 GOTO 430


2210 REM *****  LINK SUBROUTINE  *****
     *********************************
```

```
2220 W2=W/2
2230 Q1=.1726*VPH*EF    ! LINEAL SOURCE STRENGTH PARALLEL TO HIGHWAY
                          IN MICRO-GRAMS/(METER*SEC)
2240 XD=XL2(IL)-XL1(IL)
2250 YD=YL2(IL)-YL1(IL)
2260 LB=DEG(ACOS(ABS(XD)/LL(IL)))    ! LINK BEARING
2270 IF XD>0 AND YD>=0 THEN LB=90-LB
2280 IF XD>=0 AND YD<0 THEN LB=90+LB
2290 IF XD<0 AND YD<=0 THEN LB=270-LB
2300 IF XD<=0 AND YD>0 THEN LB=270+LB
2310 PHI=ABS(BRG-LB)    ! WIND ANGLE WITH RESPECT TO LINK
2320 IF PHI<=90 THEN 2340
2330 IF PHI>=270 THEN PHI=ABS(PHI-360) ELSE PHI=ABS(PHI-180)
2340 IF PHI<20 THEN 2430
2350 IF PHI<50 THEN 2410
2360 IF PHI<70 THEN 2390
2370 BASE=4
2380 GOTO 2440
2390 BASE=2
2400 GOTO 2440
2410 BASE=1.5
2420 GOTO 2440
2430 BASE=1.1
2440 PHI=RAD(PHI)    ! DEGREES TO RADIANS
2450 IF PHI>1.5706 THEN PHI=1.5706
2460 IF PHI<.00017 THEN PHI=.00017

2470 REM *****  DEPRESSED SECTION  *****
2480 IF HL(IL)<-1.5 THEN 2510
2490 DSTR,HDS=1
2500 GOTO 2540
2510 HDS=HL(IL)
2520 DSTR=.72*ABS(HDS)^.83    ! RESIDENCE TIME FACTOR


2530 REM *****  SIGMA Z POWER CURVE  *****
2540 TR=DSTR*W2/U    ! RESIDENCE TIME
2550 SGZ1=LOG((1.8+.11*TR)*(ATIM/30)^.2)    ! LOG(SIGMA Z) AT W2
2560 PZ2=(SZ10-SGZ1)/(DREF-LOG(W2))
2570 PZ1=EXP((SZ10+SGZ1-PZ2*(DREF+LOG(W2)))/2)
2580 RETURN



2590 REM *****  CALINE3 SUBROUTINE  *****
     ***********************************


2600 SIGN=1    ! DETERMINES DIRECTION ALONG LINK
                 +1 --> UPWIND ELEMENTS
                 -1 --> DOWNWIND ELEMENTS
2610 NE=0,STP,FINI=1    ! ELEMENT NUMBER, STEP FACTOR AND
                          LOOP END INITIALIZATION
2620 IF SIGN=1 AND UWL<=0 AND DWL<0 THEN SIGN=-1
2630 IF SIGN=-1 AND UWL>0 AND DWL>=0 THEN RETURN

2640 REM *****  ELEMENT LOOP  *****
2650 ED1=0
2660 ED2=SIGN*W    ! ELEMENT LIMITS
```

```
2670 IF SIGN=-1 THEN 2750
2680 IF ED1<=DWL AND ED2<=DWL THEN 3560
2690 IF ED1>DWL AND ED2<UWL THEN 2810
2700 IF ED1<=DWL THEN ED1=DWL
2710 IF ED2<UWL THEN 2810
2720 ED2=UWL
2730 NE,SIGN=-1
2740 GOTO 2810
2750 IF ED1>=UWL AND ED2>=UWL THEN 3560
2760 IF ED1<UWL AND ED2>DWL THEN 2810
2770 IF ED1>=UWL THEN ED1=UWL
2780 IF ED2>DWL THEN 2810
2790 ED2=DWL
2800 FINI=0
2810 EL2=ABS(ED2-ED1)/2   ! ELEMENT HALF-DISTANCE
2820 ECLD=(ED1+ED2)/2   ! ELEMENT CENTERLINE DISTANCE
2830 ELL2=W2/COS(PHI)+(EL2-W2*TAN(PHI))*SIN(PHI)
     ! EQUIVALENT LINE HALF-LENGTH
2840 IF PHI>=ATAN(W2/EL2) THEN CSL2=W2/SIN(PHI) ELSE
     CSL2=EL2/COS(PHI)   ! CENTRAL SUB-ELEMENT HALF-LENGTH
2850 EM2=ABS((EL2-W2/TAN(PHI))*SIN(PHI))   ! CENTRAL SUB-ELEMENT
                                             HALF-WIDTH
2860 EN2=(ELL2-EM2)/2   ! PERIPHERAL SUB-ELEMENT WIDTH

2870 REM *****  RECEPTOR DISTANCE LOOP  *****
2880 QE=Q1*CSL2/W2   ! CENTRAL SUB-ELEMENT LINEAL SOURCE STRENGTH
2890 FET=(ECLD+D*TAN(PHI))*COS(PHI)   ! ELEMENT FETCH
2900 HYP=ECLD^2+D^2
2910 SIDE=FET^2
2920 IF SIDE>HYP THEN YE=0 ELSE YE=SQRT(HYP-SIDE)
     ! Y DISTANCE FROM ELEMENT CENTER TO RECEPTOR

2930 REM *****  DETERMINE SIGMA Y AND SIGMA Z  *****
2940 IF FET<=-CSL2 THEN 3620   ! ELEMENT DOES NOT CONTRIBUTE
2950 IF FET>=CSL2 THEN 2990
2960 REM ** RECEPTOR WITHIN ELEMENT **
2970 QE=QE*(FET+CSL2)/(2*CSL2)
2980 FET=(CSL2+FET)/2
2990 SGZ=PZ1*FET^PZ2   ! SIGMA Z
3000 KZ=SGZ^2*U/(2*FET)   ! VERTICAL DIFFUSIVITY ESTIMATE
3010 SGY=PY1*FET^PY2   ! SIGMA Y
3020 FAC1=.399/(SGZ*U) ! SOURCE STRENGTH - WIND SPEED FACTOR

3030 REM *****  ADJUSTMENT FOR ELEMENT END EFFECT  *****
                 (POLYNOMIAL APPROXIMATION)
3040 Y(1)=YE+ELL2
3050 Y(2)=Y(1)-EN2
3060 Y(3)=Y(2)-EN2
3070 Y(4)=Y(3)-2*EM2
3080 Y(5)=Y(4)-EN2
3090 Y(6)=Y(5)-EN2
3100 FOR I=1 TO 6   ! SUB-ELEMENT SOURCE STRENGTH LOOP
3110 LIM=ABS(Y(I)/SGY)
3120 T=1/(1+.23164*LIM)
3130 ARG=LIM^2/-2
3140 IF LIM>5 THEN INTG(I)=0 ELSE INTG(I)=.3989*EXP(ARG)*
     (.3194*T-.3566*T^2+1.7815*T^3-1.8213*T^4+1.3303*T^5)
3150 NEXT I
3160 FAC2=0
3170 FOR I=1 TO 5
```

```
3180 IF SGN(Y(I))=SGN(Y(I+1)) THEN PD=ABS(INTG(I+1)-INTG(I)) ELSE
     PD=1-INTG(I)-INTG(I+1)    ! NORMAL PROBABILITY DENSITY FUNCTION
3190 FAC2=FAC2+PD*QE*WT(I)
3200 NEXT I
3210 FACT=FAC1*FAC2

3220 REM *****  DEPRESSED SECTION  *****
3230 IF HDS<-1.5 AND ABS(D)<W2-3*HDS THEN 3240 ELSE 3260
3240 IF ABS(D)<=W2 THEN FACT=FACT*DSTR ELSE
     FACT=FACT*(DSTR-(DSTR-1)*(ABS(D)-W2)/(-3*HDS))
     ! ADJUST FOR DEPRESSED SECTION WIND SPEED

3250 REM *****  DEPOSITION CORRECTION  *****
3260 FAC3=0
3270 IF V1=0 THEN 3350
3280 ARG=V1*SGZ/(KZ*SQRT(2))+(Z+H)/(SGZ*SQRT(2))
3290 IF ARG>5 THEN 3560
3300 T=1/(1+.47047*ARG)
3310 ERFC=(.3480242*T-.0958798*T^2+.7478556*T^3)*EXP(-1*ARG^2)
3320 FAC3=(SQRT(2*PI)*V1*SGZ*EXP(V1*(Z+H)/KZ+.5*(V1*SGZ/KZ)^2)
     *ERFC)/KZ
3330 IF FAC3>2 THEN FAC3=2

3340 REM *****  SETTLING CORRECTION  *****
3350 IF VS=0 THEN 3390
3360 FAC4=EXP(-VS*(Z-H)/(2*KZ)-(VS*SGZ/KZ)^2/8)
3370 FACT=FACT*FAC4

3380 REM *****  INCREMENTAL CONCENTRATION  *****
3390 CNT,FAC5=0
3400 EXLS=0
3410 ARG1=-.5*((Z+H+2*CNT*MIXH)/SGZ)^2
3420 IF ARG1<-44 THEN EXP1=0 ELSE EXP1=EXP(ARG1)
3430 ARG2=-.5*((Z-H+2*CNT*MIXH)/SGZ)^2
3440 IF ARG2<-44 THEN EXP2=0 ELSE EXP2=EXP(ARG2)
3450 FAC5=FAC5+EXP1+EXP2
3460 IF MIXH>=1000 THEN 3530    ! BYPASS MIXING HEIGHT CALCS.
3470 IF EXP1+EXP2+EXLS=0 AND CNT<=0 THEN 3530
3480 IF CNT>0 THEN 3500 ELSE CNT=ABS(CNT)+1
3490 GOTO 3400
3500 CNT=-CNT
3510 EXLS=EXP1+EXP2
3520 GOTO 3410
3530 INC=FACT*(FAC5-FAC3)
     ! INCREMENTAL CONCENTRATION FROM ELEMENT
3540 C(IL,IR)=C(IL,IR)+INC    ! SUMMATION OF CONCENTRATIONS
3550 IF FINI=0 THEN RETURN
3560 NE=NE+1
3570 STP=BASE^NE    ! STEP FACTOR
3580 IF NE=0 THEN 2630
3590 ED1=ED2
3600 ED2=ED2+SIGN*STP*W
3610 GOTO 2670
3620 IF SIGN=1 THEN 3560
3630 RETURN
3640 END
```

APPENDIX B - CALINE3

(FORTRAN VERSION)

```
          C
          C **  NL<2  **
          C
0373        300 FORMAT (//,6X,42HIII.  RECEPTOR LOCATIONS AND MODEL RESULTS//)
0374        305 FORMAT (//,7X,41HIV.  MODEL RESULTS (RECEPTOR-LINK MATRIX)//)
0375        310 FORMAT (29X,37H*        COORDINATES (M)           *  CO)
0376        320 FORMAT (8X,8HRECEPTOR,13X,
               *     39H*       X         Y          Z       * (PPM))
0377        330 FORMAT (4X,25(1H-),1H*,31(1H-),1H*,7(1H-))
          C
          C **  MODEL RESULTS  **
0378        340 FORMAT (4X,I2,2H. ,5A4,1X,1H*,4X,F6.0,3X,F6.0,3X,F6.1,
               *     3X,1H*,F5.1)
          C
          C **  NL>1  **
          C
0379        390 FORMAT (29X,1H*,31X,7H* TOTAL,1X,1H*)
0380        400 FORMAT (8X,8HRECEPTOR,13X,
               *     41H*       X         Y          Z    .  * (PPM) *,10(3X,A1,1X))
0381        420 FORMAT (4X,25(1H-),1H*,31(1H-),1H*,7(1H-),1H*)
0382        440 FORMAT (4X,I2,2H. ,5A4,1X,1H*,4X,F6.0,3X,F6.0,3X,F6.1,
               *     3X,1H*,F5.1,2X,1H*,10(1X,F4.1))
0383        450 FORMAT (29X,1H*,31X,8H*  TOTAL)
0384        460 FORMAT (29X,24H*        COORDINATES (M),8X,8H*  + AMB)
0385        470 FORMAT (8X,8HRECEPTOR,13X,26H*      X         Y          Z,
               *     6X,8H*  (PPM))
0386        480 FORMAT (4X,25(1H-),1H*,31(1H-),1H*,8(1H-))
0387        490 FORMAT (4X,I2,2H. ,5A4,1X,1H*,4X,F6.0,3X,F6.0,3X,F6.1,
               *     3X,1H*,F6.1)
0388        500 FORMAT (29X,1H*)
0389        510 FORMAT (8X,8HRECEPTOR,13X,1H*,20(3X,A1,1X))
0390        520 FORMAT (4X,25(1H-),1H*)
0391        530 FORMAT (4X,I2,2H. ,5A4,1X,1H*,20(1X,F4.1))
0392       9999 STOP
0393            END
```

CALIFORNIA DEPARTMENT OF TRANSPORTATION

TRANSPORTATION LABORATORY

FOUNDED IN 1912

APPENDIX C - CALINE3

(PROGRAMMABLE CALCULATOR VERSION)

1. Program Description

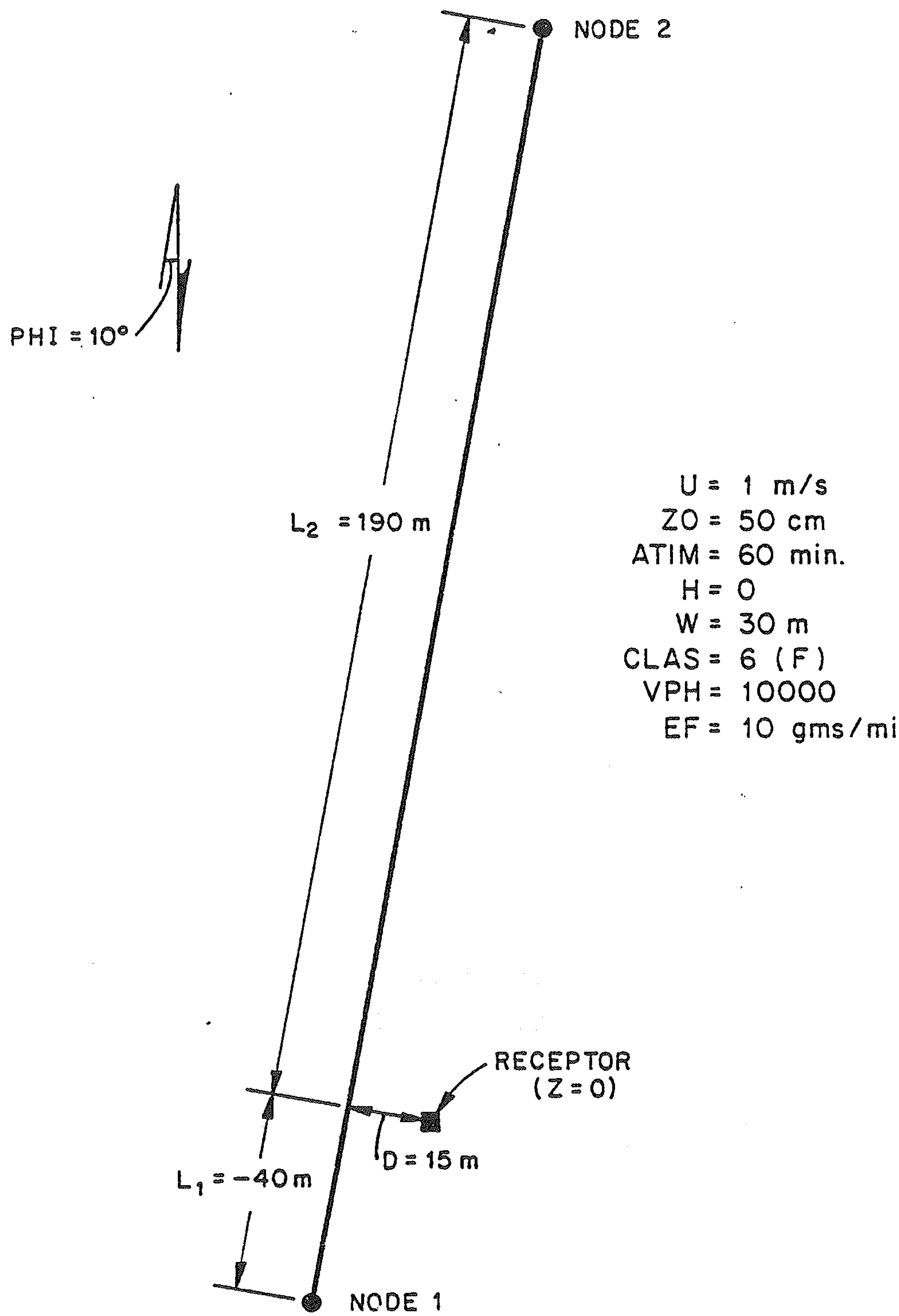
The programmable calculator version of CALINE3 is designed for the potential model user with no large-scale computer facilities available as an alternative to bulky and necessarily incomplete nomographic solutions. Several options contained in the BASIC and FORTRAN versions of the model have been deleted to satisfy program size constraints. However, the core of the CALINE3 computational procedure has been preserved so that answers obtained from the abbreviated version will, except under specific circumstances, accurately reproduce results from the full-scale versions of the model. The options which are not available are deposition and settling velocity and mixing height. For the majority of CALINE3 applications, however, these options will not be needed.

The programmable calculator version of CALINE3 is divided into an initialization program, a program for dispersion curve generation, and a main program. The initialization program stores the factors used for a third order polynomial approximation to the normal probability density function. As long as storage registers S5 through S8 on the HP-67/97 and 25 through 28 on the TI-59 remain unaltered, the initialization program does not need to be reexecuted. On the TI-59, the initialization program is combined with the dispersion curve program.

The dispersion curve program computes and stores the parameters of the power curve approximations to the vertical and horizontal dispersion parameters, σ_z and σ_y, with adjustments made for mixing zone residence time (TR) and depressed section depth. It also stores wind speed (U) and an aggregated conversion factor (FPPM*0.1726/2π). If the inputs to the dispersion curve program (U, ZO, ATIM, H, W, CLAS) remain constant, a single execution may be followed by multiple main program runs.

The main program takes the values stored by the preceding initialization and dispersion curve programs plus additional information on wind direction, link-receptor geometry, source strength and ambient level, and sums pollutant concentrations at the receptor for each element of the link. To simplify the geometry involved in this process, the element growth factor (BASE) is kept equal to one. Computation time is approximately 40 seconds/element for the HP-67/97, and 60 seconds/element for the TI-59. For elements downwind of the receptor, computations are bypassed. The latest value of CSUM is displayed after each element computation so that the user may interrupt when the desired convergence is obtained. If the program is interrupted at some other point, the HP-67/97 user should check for proper primary-secondary storage register alignment before proceeding with another run. For parallel wind runs, extrapolation may be used to avoid excessive run time. Figure 19 can be consulted in regards to extrapolations for parallel wind, F stability cases.

As shown in Figure C-1, the programmable calculator version treats each receptor-link combination separately. The link nodal coordinates (L_1, L_2) are specified along the link axis and relative to the receptor location. Unless PHI=90°, node 2 should always be upwind of node 1. Since no allowance is made for partial contributions from elements (occurring when -CSL2<FET<CSL2), receptors within or upwind of the mixing zone are not permitted in this version of the model. A discrete jump in model results when D=W2 and PHI goes from just below to just above 45° occurs because of this limitation. As D increases this discrepancy rapidly becomes insignificant.



EXAMPLE PROBLEM

FIGURE C-1

The user is further cautioned when dealing with depressed sections ($H<-1.5m$) and fill sections. For fill sections, the user must remember to input a value of zero for H. For depressed sections when D<W2+ABS(3*H), the final result, CSUM, should be adjusted as follows:

$$CSUM' = (CSUM-AMB)*(DSTR- \frac{(DSTR-1)*(D-W2)}{3*ABS(H)}) + AMB$$

Where, $DSTR = 0.72*ABS(H)^{0.83}$

ABS(H) = Absolute value of H

The calculator version of CALINE3 has been programmed specifically for Hewlett-Packard Models 67 and 97 and Texas Instruments Model 59 programmable calculators. According to manufacturer specifications, programs written for the HP-67/97 are compatible with the new HP-41C. The user should be aware that the program listed in this report has not as yet been test run on the HP-41C.

2. Restrictions

In addition to the general restrictions listed under 8.1.6, the following data input restrictions apply to the programmable calculator version of CALINE3:

a) $D \leq W2$ (Receptor downwind of mixing zone)
b) $0° \leq PHI \leq 90°$
c) $L_2 > L_1$ (Node 2 upwind of node 1 when $PHI \neq 90°$)

3. Example Problem

The example problem shown in Figure C-1 is meant to assist the user in verifying his version of the model. It also serves as certified output which can be used to check model performance before and after a series of critical runs. It is strongly recommended that the user follow this checking procedure in order to minimize the chance of human or machine error affecting critical results.

The example problem is essentially the same, except for link length, as the standard run used in the sensitivity analysis portion of this report. Table C-1 lists the output by element displayed by the calculator (CSUM) plus additional parameters useful in program troubleshooting.

4. User Instructions and Coding

User instructions and coding for the initialization, dispersion curve and main programs are given in HP and TI format following Table C-1.

TABLE C-1

HP-67/97 EXAMPLE PROBLEM OUTPUT
AND INTERNAL PARAMETERS

ECLD (m)	FET (m)	YE (m)	SGZ (m)	SGY (m)	FAC2* $\sqrt{2\pi}/QE$ (m-sec/μg)	CSUM (ppm)
-15	(Bypass Computations)					--
15	17.38	12.17	4.28	2.12	2.051	2.34
45	46.92	6.96	7.14	4.99	2.328	3.93
75	76.47	1.75	9.20	7.60	2.343	5.18
105	106.01	3.46	10.89	10.07	2.076	6.11
135	135.55	8.67	12.36	12.44	1.642	6.76
165	165.10	13.88	13.69	14.74	1.246	7.20

User Instructions

1 CALINE3 - INITIALIZATION 2

Execute

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	EXECUTE		A		a_3
	Stores factors for				
	3rd order polynomial				
	approximation to normal				
	probability density function.				
	$Q(X) = Z(X)(a_1T+a_2T^2+a_3T^3)+\varepsilon(X)$				
	where, $X = LIM = ABS(Y(i)/SGY)$				
	$T = 1/(1+pX)$				
	$Z(X) = \exp(-X^2/2)/\sqrt{2\pi}$				
	$Q(X) = \int_X^\infty Z(x)dx$				
	$\lvert\varepsilon(X)\rvert<1x10^{-5}$				
	References:				
	Abramowitz and Stegun,				
	Handbook of Mathematical Functions,				
	NBS, 1964				

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
	f LBL A	31 25 11	
	f P/S	31 42	
	.	83	
	3	03	
	3	03	
	2	02	
	6	06	
	7	07	p
	STO 5	33 05	
010	.	83	
	4	04	
	3	03	
	6	06	
	1	01	
	8	08	
	3	03	
	6	06	a_1
	STO 6	33 06	
	.	83	
020	1	01	
	2	02	
	0	00	
	1	01	
	6	06	
	7	07	
	6	06	
	CHS	42	a_2
	STO 7	33 07	
	.	83	
030	9	09	
	3	03	
	7	07	
	2	02	
	9	09	
	8	08	a_3
	STO 8	33 08	
	f P/S	31 42	
	R/S	84	

REGISTERS

S5	S6	S7	S8
p	a_1	a_2	a_3

LABELS

FLAGS

SET STATUS

FLAGS	TRIG	DISP
ON OFF		
0 [ ] [ ]	DEG [ ]	FIX [ ]
1 [ ] [ ]	GRAD [ ]	SCI [ ]
2 [ ] [ ]	RAD [ ]	ENG [ ]
3 [ ] [ ]		n ___

User Instructions

CALINE3 - DISPERSION CURVES

Execute

U	Z0	ATIM	H	W

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Store Input	U(m/s)	STO	A	
		Z0(cm)	STO	B	
		ATIM(min)	STO	C	
		H(m)	STO	D	
		W(m)	STO	E	
		CLAS	h	ST I	
2	Execute		A		H(m)
	Computes and stores parameters of power curve approximations to vertical and horizontal dispersion parameters, σ_z and σ_y.				
	$\sigma_z = PZ1*x^{PZ2}$				
	$\sigma_y = PY1*x^{PY2}$				
	where, X = Downwind Distance (m)				
	Also stores U, H, W2 and conversion factor for use in main program				

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f LBL A	31 25 11	
	.	83	
	4	04	
	6	06	
	STO 1	33 01	
	.	83	
	2	02	
	9	09	
	STO 2	33 02	
010	.	83	
	1	01	
	8	08	
	STO 3	33 03	
	.	83	
	1	01	
	1	01	
	STO 4	33 04	
	.	83	
	0	00	
020	8	08	
	7	07	
	STO 5	33 05	
	.	83	
	0	00	
	5	05	
	7	07	
	STO 6	33 06	
	RCL (i)	34 24	AY1(CLAS)
	RCL C	34 13	
030	3	03	
	÷	81	
	.	83	
	2	02	
	h y^x	35 63	AFAC
	STO 0	33 00	
	x	71	
	RCL B	34 12	
	3	03	
	÷	81	
040	.	83	
	2	02	
	h y^x	35 63	
	x	71	PY1
	STO 8	33 08	
	1	01	
	8	08	
	3	03	
	1	01	
	STO 1	33 01	
050	1	01	
	1	01	
	5	05	
	5	05	
	STO 2	33 02	
	7	07	
	1	01	
	7	07	
	STO 3	33 03	
	4	04	
060	3	03	
	8	08	
	STO 4	33 04	
	3	03	
	4	04	
	6	06	
	STO 5	33 05	
	2	02	
	2	02	
	7	07	
070	STO 6	33 06	
	RCL (i)	34 24	AY2(CLAS)
	RCL 0	34 00	
	x	71	
	RCL B	34 12	
	3	03	
	÷	81	
	.	83	
	0	00	
	7	07	
080	h y^x	35 63	
	x	71	
	RCL 8	34 08	
	÷	81	
	f LN	31 52	
	EEX	43	
	4	04	
	f LN	31 52	DREF
	÷	81	PY2
	STO 9	33 09	
090	1	01	
	1	01	
	1	01	
	2	02	
	STO 1	33 01	
	5	05	
	6	06	
	6	06	
	STO 2	33 02	
	3	03	
100	5	05	
	3	03	
	STO 3	33 03	
	2	02	
	1	01	
	9	09	
	STO 4	33 04	
	1	01	
	2	02	
	4	04	
110	STO 5	33 05	
	5	05	
	6	06	
	STO 6	33 06	
	RCL (i)	34 24	AZ(CLAS)
	RCL 0	34 00	
	x	71	
	RCL B	34 12	
	1	01	
	0	00	
120	÷	81	
	.	83	
	0	00	
	7	07	
	h y^x	35 63	
	x	71	
	f LN	31 52	SZ10
	STO 1	33 01	
	RCL E	34 15	
	2	02	
130	÷	81	W2
	STO 5	33 05	
	RCL A	34 11	
	÷	81	Depressed Section Adjustment to Residence Time
	RCL D	34 14	
	1	01	
	.	83	
	5	05	
	CHS	42	
	g x<y	32 71	
140	GTO 1	22 01	
	h R↓	35 53	
	h ABS	35 64	
	.	83	
	8	08	
	3	03	
	h y^x	35 63	
	.	83	
	7	07	
	2	02	
150	x	71	DSTR
	x	71	
	GTO 2	22 02	
	f LBL 1	31 25 01	
	h R↓	35 53	
	h R↓	35 53	
	f LBL 2	31 25 02	TR
	.	83	
	1	01	
	1	01	
160	x	71	
	1	01	
	.	83	
	8	08	
	+	61	
	RCL C	34 13	
	3	03	
	0	00	
	÷	81	
	.	83	
170	2	02	
	h y^x	35 63	
	x	71	
	f LN	31 52	SGZ1
	STO 2	33 02	
	-	51	
	EEX	43	
	4	04	
	f LN	31 52	
	STO 6	33 06	
180	RCL 5	34 05	
	f LN	31 52	
	-	51	
	÷	81	PZ2
	STO 7	33 07	
	RCL 1	34 01	
	RCL 2	34 02	
	+	61	
	RCL 6	34 06	
	RCL 5	34 05	
190	f LN	31 52	
	+	61	
	RCL 7	34 07	
	x	71	
	-	51	
	2	02	
	÷	81	
	g e^x	32 52	PZ1
	STO 6	33 06	
	f P⇄S	31 42	
200	2	02	
	.	83	
	4	04	Conversion Factors $FPPM = 0.1726 / 2\pi$
	0	00	
	3	03	
	6	06	
	EEX	43	
	5	05	
	CHS	42	
	RCL A	34 11	
210	÷	81	
	STO 9	33 09	
	f P⇄S	31 42	
	RCL D	34 14	Depressed Section H = 0
	f x≤0	31 71	
	CLX	44	
	STO 4	33 04	
	R/S	84	
220			

REGISTERS

0	1	2	3	4	5	6	7	8	9
AFAC	SZ10	SGZ1		H(m)	W2(m)	DREF PZ1	PZ2	PY1	PY2

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
					p	a_1	a_2	a_3	$2.4 \times 10^5 / U$

A	B	C	D	E	I
U (m/s)	ZD(cm)	ATIM(min)	H(m)	W(m)	CLAS(F=6)

LABELS

A	B	C	D	E
Execute				
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON OFF	TRIG	DISP
0	☐ ☐	DEG ☐	FIX ☐
1	☐ ☐	GRAD ☐	SCI ☐
2	☐ ☐	RAD ☐	ENG ☐
3	☐ ☐		n ___

User Instructions

CALINE 3 - MAIN PROGRAM

Execute PHI	L_1	L_2	D	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	STORE INPUT	PHI(deg)	STO	A	
		L_1(m)	STO	B	
		L_2(m)	STO	C	
		D (m)	STO	D	
		Z (m)	STO	2	
		VPH	↑		
		EF(gm/mi)	x		
			STO	3	
2	EXECUTE	AMB(ppm)	A		CSUM(ppm)
	Execution will pause at approximate				
	40 second intervals displaying current				
	value of CSUM. User may safely interrupt				
	at this time. However, contents of y				
	register must be maintained if execution				
	is to be resumed.				
3	To perform additional runs:				
	a. Check to see that input parameters				
	to dispersion curve program have				
	not changed.				
	b. Assure proper alignment of primary				
	and secondary memories.		RCL	9	PY2
	c. Re-initialize L_1.	L_1(m)	STO	B	
	d. Store altered inputs in appropriate				
	storage registers.				
	e. Go to Step 2.				

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f LBL A	31 25 11	
	STO 0	33 00	
	RCL A	34 11	
	RCL 5	34 05	
	f R→P	31 72	
	g x>y	32 81	
	h x⇄y	35 52	EN2
	f P⇄S	31 42	
	STO 3	33 03	
010	−	51	EM2
	STO 4	33 04	
	f P⇄S	31 42	
	RCL B	34 12	L_1
	f x>0	31 81	
	GTO 1	22 01	
	RCL 5	34 05	
	2	02	
	×	71	
	STO 1	33 01	Initialize
020	÷	81	
	DSP 0	23 00	ECLD
	f RND	31 24	
	DSP 2	23 02	
	RCL 1	34 01	
	×	71	
	f LBL 1	31 25 01	
	RCL 5	34 05	
	+	61	
	f LBL B	31 25 12	
030	STO B	33 12	
	h CF 0	35 61 00	ECLD
	f x<0	31 71	
	h SF 0	35 51 00	
	RCL D	34 14	
	h F? 0	35 71 00	
	GTO 2	22 02	
	h x⇄y	35 52	
	f LBL 2	31 25 02	
	g R→P	32 72	
040	h x⇄y	35 52	Compute FET & YE
	h ABS	35 64	
	RCL A	34 11	
	g x>y	32 81	
	GTO 3	22 03	
	h F? 0	35 71 00	
	GTO 4	22 04	
	f LBL 3	31 25 03	
	−	51	
	h ABS	35 64	
050	h x⇄y	35 52	
	f R→P	31 72	
	h F? 0	35 71 00	
	h x⇄y	35 52	
	STO 1	33 01	
	RCL 9	34 09	
	h y^x	35 63	FET, YE
	RCL 8	34 08	
	×	71	SGY
	STO E	33 15	
060	RCL 1	34 01	
	RCL 7	34 07	
	h y^x	35 63	
	RCL 6	34 06	
	×	71	SGZ
	h STI	35 33	
	0	00	
	STO 1	33 01	
	h R↑	35 54	YE
	f P⇄S	31 42	
070	RCL 3	34 03	
	2	02	
	×	71	
	+	61	
	RCL 4	34 04	
	+	61	Y(1)
	STO 0	33 00	
	0	00	
	h CF 0	35 61 00	
	h CF 1	35 61 01	
080	g GSB f a	32 22 11	
	RCL 3	34 03	
	g GSB f a	32 22 11	
	4	04	
	g GSB f b	32 22 12	1/WT(1)
	RCL 3	34 03	
	g GSB f a	32 22 11	
	4	04	
	ENTER↑	41	
	3	03	
090	÷	81	Adjust for Element End Effect
	g GSB f b	32 22 12	
	RCL 4	34 04	
	2	02	
	×	71	
	g GSB f a	32 22 11	
	1	01	
	g GSB f b	32 22 12	
	RCL 3	34 03	
	g GSB f a	32 22 11	
100	4	04	
	ENTER↑	41	
	3	03	1/WT(4)
	÷	81	
	g GSB f b	32 22 12	
	RCL 3	34 03	
	g GSB f a	32 22 11	1/WT(5)
	4	04	
	g GSB f b	32 22 12	
	RCL 9	34 09	
110	f P⇄S	31 42	
	STO × 1	33 71 01	
	h RC I	35 34	SGZ
	STO ÷ 1	33 81 01	
	RCL A	34 11	
	RCL 3	34 03	
	h 1/x	35 62	
	f R→P	31 72	
	g x≤y	32 71	
	h x⇄y	35 52	
120	STO ÷ 1	33 81 01	QE(gms/mi-hr)
	RCL 2	34 02	
	RCL 4	34 04	
	+	61	
	g GSB f c	32 22 13	EXP1
	RCL 2	34 02	
	RCL 4	34 04	
	−	51	
	g GSB f c	32 22 13	EXP2
	+	61	
130	RCL 1	34 01	
	×	71	INC
	STO + 0	33 61 00	
	f LBL 4	31 25 04	
	RCL C	34 13	L_2
	RCL B	34 12	
	RCL 5	34 05	
	2	02	
	×	71	
	+	61	
140	g x>y	32 81	ECLD, L_2
	GTO 9	22 09	
	RCL 0	34 00	CSUM
	h PAUSE	35 72	
	h R↓	35 53	
	GTO B	22 12	
	f LBL 9	31 25 09	
	RCL 0	34 00	
	R/S	84	
	g LBL f a	32 25 11	Subroutine a
150	STO − 0	33 51 00	
	h R↓	35 53	Y(1)
	RCL 0	34 00	
	f x<0	31 71	
	h SF 0	35 51 00	
	RCL E	34 15	
	÷	81	
	h ABS	35 64	LIM
	STO 1	33 01	
	RCL 5	34 05	P
160	×	71	
	1	01	
	+	61	
	h 1/x	35 62	T
	STO 2	33 02	
	3	03	
	h y^x	35 63	
	RCL 8	34 08	a_3, T^3
	×	71	
	RCL 2	34 02	
170	g x^2	32 54	a_2, T^2
	RCL 7	34 07	
	×	71	
	+	61	
	RCL 2	34 02	a_1, T
	RCL 6	34 06	
	×	71	
	+	61	
	RCL 1	34 01	
	g x^2	32 54	
180	2	02	
	÷	81	
	CHS	42	ARG
	g e^x	32 52	
	×	71	$\sqrt{2\pi}$ * INTG(1)
	h RTN	35 22	
	g LBL f b	32 25 12	Subroutine b 1/WT(1) INTG(i),INTG(i+1)
	STO 1	33 01	
	h R↓	35 53	
	STO 2	33 02	
190	h F? 0	35 71 00	
	GTO 5	22 05	
	f LBL 6	31 25 06	
	−	51	
	h ABS	35 64	PD*$\sqrt{2\pi}$
	GTO 7	22 07	
	f LBL 5	31 25 05	
	h F? 1	35 71 01	
	GTO 6	22 06	
	+	61	
200	h π	35 73	π
	2	02	
	×	71	
	f $\sqrt{x}$	31 54	
	h x⇄y	35 52	
	−	51	PD*$\sqrt{2\pi}$
	h SF 1	35 51 01	
	f LBL 7	31 25 07	
	RCL 1	34 01	
	÷	81	PD*WT(i)*$\sqrt{2\pi}$
210	f P⇄S	31 42	
	STO + 1	33 61 01	FAC2*$\sqrt{2\pi}$/QE
	f P⇄S	31 42	
	RCL 2	34 02	
	h RTN	35 22	
	g LBL f c	32 25 13	Subroutine c SGZ, Z±H
	h RC I	35 34	
	÷	81	
	g x^2	32 54	
	2	02	
220	÷	81	
	CHS	42	
	g e^x	32 52	ARG1 or 2 EXP1 or 2
	h RTN	35 22	

REGISTERS

0	1	2	3	4	5	6	7	8	9
CSUM	FET see 212	Z	VPH*EF	H	W2	PZ1	PZ2	PY1	PY2

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Y(1)	LIM 1/WT(1)	T INTG(1)	EN2	EM2	P	a_1	a_2	a_3	2.4×10^{-5} U

A	B	C	D	E	I
PHI (deg)	L_1(m)	L_2(m)	D (m)	SGY (m)	SGZ (m)

LABELS

A	B	C	D	E
Execute				
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON OFF	TRIG	DISP
0	[ ] [ ]	DEG [X]	FIX [X]
1	[ ] [ ]	GRAD [ ]	SCI [ ]
2	[ ] [ ]	RAD [ ]	ENG [ ]
3	[ ] [ ]		n ___

TITLE CALINE 3 - INITIALIZATION AND DISPERSION PROGRAM PAGE 1 OF 4

TI Programmable Program Record

PROGRAMMER Paul Benson DATE 2/80

Partitioning (Op 17) 7.1.9.2.9 Library Module ______ Printer ______ Cards ______

PROGRAM DESCRIPTION

Stores factors for 3rd order polynomial approximation to the normal probability density function, and computes and stores parameters of power curve approximations to vertical and horizontal dispersion parameters, σ_z and σ_y.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1	Store Input	U (m/s)	STO	0	1	
		ZO (cm)	STO	0	2	
		ATIM (min)	STO	0	3	
		H (m)	STO	0	4	
		W (m)	STO	0	5	
		CLAS	STO	0	6	
2	Execute		A			H (m)

USER DEFINED KEYS		DATA REGISTERS			
A	Execute	10	AFAC	20	
B		11	SZ10	21	
C		12	SGZ1	22	
D		13		23	
E		14	H (m)	24	
A'		15	W2 (m)	25	p
B'		16	PZ1	26	a_1
C'		17	PZ2	27	a_2
D'		18	PY1	28	a_3
E'		19	PY2	29	$2.4x10^5/U$

LABELS (Op 08)

FLAGS 0 1 2 3 4 5 6 7 8 9

TITLE CALINE3 - INITIALIZATION AND DISPERSION PROGRAM PAGE 2 OF 4

TI Programmable Coding Form

PROGRAMMER Paul Benson DATE 2/80

LOC	CODE	KEY	COMMENTS
000	76	LBL	
001	11	A	
002	93	.	
003	03	3	
004	03	3	
005	02	2	
006	06	6	
007	07	7	p
008	42	STO	
009	25	25	
010	93	.	
011	04	4	
012	03	3	
013	06	6	
014	01	1	
015	08	8	
016	03	3	
017	06	6	a_1
018	42	STO	
019	26	26	
020	93	.	
021	01	1	
022	02	2	
023	00	0	
024	01	1	
025	06	6	
026	07	7	
027	06	6	
028	94	+/-	a_2
029	42	STO	
030	27	27	
031	93	.	
032	09	9	
033	03	3	
034	07	7	
035	02	2	
036	09	9	
037	08	8	a_3
038	42	STO	
039	28	28	
040	01	1	
041	00	0	
042	44	SUM	
043	06	06	
044	93	.	
045	04	4	
046	06	6	
047	42	STO	
048	11	11	
049	93	.	
050	02	2	
051	09	9	
052	42	STO	
053	12	12	
054	93	.	
055	01	1	
056	08	8	
057	42	STO	
058	13	13	
059	93	.	
060	01	1	
061	01	1	
062	42	STO	
063	14	14	
064	93	.	
065	00	0	
066	08	8	
067	07	7	
068	42	STO	
069	15	15	
070	93	.	
071	00	0	
072	05	5	
073	07	7	
074	42	STO	
075	16	16	
076	73	RC*	
077	06	06	AY1(CLAS)
078	65	×	
079	53	(	
080	53	(	
081	43	RCL	
082	03	03	
083	55	÷	
084	03	3	
085	54	)	
086	45	YX	
087	93	.	
088	02	2	
089	54	)	AFAC
090	42	STO	
091	10	10	
092	65	×	
093	53	(	
094	43	RCL	
095	02	02	
096	55	÷	
097	03	3	
098	54	)	
099	45	YX	
100	93	.	
101	02	2	
102	95	=	PY1
103	42	STO	
104	18	18	
105	01	1	
106	08	8	
107	03	3	
108	01	1	
109	42	STO	
110	11	11	
111	01	1	
112	01	1	
113	05	5	
114	05	5	
115	42	STO	
116	12	12	
117	07	7	
118	01	1	
119	07	7	
120	42	STO	
121	13	13	
122	04	4	
123	03	3	
124	08	8	
125	42	STO	
126	14	14	
127	03	3	
128	04	4	
129	06	6	
130	42	STO	
131	15	15	
132	02	2	
133	02	2	
134	07	7	
135	42	STO	
136	16	16	
137	53	(	
138	73	RC*	
139	06	06	AY2(CLAS)
140	65	×	
141	43	RCL	
142	10	10	
143	65	×	
144	53	(	
145	43	RCL	
146	02	02	
147	55	÷	
148	03	3	
149	54	)	
150	45	YX	
151	93	.	
152	00	0	
153	07	7	
154	55	÷	
155	43	RCL	
156	18	18	
157	54	)	
158	23	LNX	
159	55	÷	

MERGED CODES

62 63 64 72 STO 73 RCL 74 SUM 83 GTO 84 92 INV SBR

TEXAS INSTRUMENTS

TITLE CALINE3 - INITIALIZATION AND DISPERSION PROGRAM PAGE 3 OF 4

PROGRAMMER Paul Benson DATE 2/80

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
160	01	1	
161	52	EE	
162	04	4	
163	23	LNX	
164	95	=	PY2
165	42	STO	
166	19	19	
167	01	1	
168	01	1	
169	01	1	
170	02	2	
171	42	STO	
172	11	11	
173	05	5	
174	06	6	
175	06	6	
176	42	STO	
177	12	12	
178	03	3	
179	05	5	
180	03	3	
181	42	STO	
182	13	13	
183	02	2	
184	01	1	
185	09	9	
186	42	STO	
187	14	14	
188	01	1	
189	02	2	
190	04	4	
191	42	STO	
192	15	15	
193	05	5	
194	06	6	
195	42	STO	
196	16	16	
197	53	(	
198	73	RC*	
199	06	06	AZ(CLAS)
200	65	×	
201	43	RCL	
202	10	10	
203	65	×	
204	53	(	
205	43	RCL	
206	02	02	
207	55	÷	
208	01	1	
209	00	0	
210	54	)	
211	45	YX	
212	93	.	
213	00	0	
214	07	7	

LOC	CODE	KEY	COMMENTS
215	54	)	
216	23	LNX	SZ10
217	42	STO	
218	11	11	
219	43	RCL	
220	05	05	
221	55	÷	
222	02	2	
223	95	=	W2
224	42	STO	
225	15	15	
226	55	÷	
227	43	RCL	
228	01	01	
229	95	=	TR
230	42	STO	
231	07	07	
232	01	1	
233	93	.	
234	05	5	
235	94	+/-	
236	32	X:T	
237	43	RCL	
238	04	04	
239	77	GE	
240	22	INV	
241	50	I×I	
242	45	YX	
243	93	.	
244	08	8	
245	03	3	
246	65	×	
247	93	.	
248	07	7	
249	02	2	
250	95	=	DSTR
251	49	PRD	
252	07	07	
253	76	LBL	
254	22	INV	
255	53	(	
256	43	RCL	
257	11	11	
258	75	-	
259	53	(	
260	53	(	
261	43	RCL	
262	07	07	
263	65	×	
264	93	.	
265	01	1	
266	01	1	
267	85	+	
268	01	1	
269	93	.	

LOC	CODE	KEY	COMMENTS
270	08	8	
271	54	)	
272	65	×	
273	53	(	
274	43	RCL	
275	03	03	
276	55	÷	
277	03	3	
278	00	0	
279	54	)	
280	45	YX	
281	93	.	
282	02	2	
283	54	)	
284	23	LNX	SGZ1
285	42	STO	
286	12	12	
287	54	)	
288	55	÷	
289	53	(	
290	01	1	
291	52	EE	
292	04	4	
293	23	LNX	
294	75	-	
295	43	RCL	
296	15	15	
297	23	LNX	
298	54	)	
299	95	=	PZ2
300	42	STO	
301	17	17	
302	53	(	
303	53	(	
304	43	RCL	
305	11	11	
306	85	+	
307	43	RCL	
308	12	12	
309	75	-	
310	53	(	
311	43	RCL	
312	17	17	
313	65	×	
314	53	(	
315	01	1	
316	52	EE	
317	04	4	
318	23	LNX	
319	[illegible]	-	

MERGED CODES

62 | 72 STO | 83 GTO
63 | 73 RCL | 84
64 | 74 SUM | 92 INV SBR

TEXAS INSTRUMENTS

CALINE3 - INITIALIZATION
TITLE AND DISPERSION PROGRAM PAGE 4 OF 4 TI Programmable Coding Form

PROGRAMMER Paul Benson DATE 2/80

LOC	CODE	KEY	COMMENTS
320	43	RCL	
321	15	15	
322	23	LNX	
323	54	)	
324	54	)	
325	54	)	
326	55	÷	
327	02	2	
328	54	)	
329	22	INV	
330	23	LNX	PZ1
331	42	STO	
332	16	16	
333	02	2	
334	93	.	
335	04	4	
336	00	0	
337	03	3	
338	06	6	
339	52	EE	
340	05	5	
341	94	+/-	
342	55	÷	
343	43	RCL	
344	01	01	
345	95	=	FPPM*.1726 / 2πU
346	42	STO	
347	29	29	
348	29	CP	
349	43	RCL	
350	04	04	
351	77	GE	
352	23	LNX	
353	32	X:T	
354	76	LBL	
355	23	LNX	
356	42	STO	
357	14	14	
358	91	R/S	End

MERGED CODES
62 63 64 72 STO 73 RCL 74 SUM 83 GTO 84 92 INV SBR

TEXAS INSTRUMENTS

TITLE CALINE 3 - MAIN PROGRAM PAGE 1 OF 4

PROGRAMMER Paul Benson DATE 2/80

TI Programmable Program Record

Partitioning (Op 17) 7,1,9,2,9 Library Module ______ Printer ______ Cards ______

PROGRAM DESCRIPTION

Sums incremental CO concentrations from a series of uniform elements for a single receptor at height Z and at distance D from the line source link. Execution ends when the link endpoint L_2 is reached.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1	Stores Input	PHI (deg)	STO	0	1	
		L_1 (m)	STO	0	2	
		L_2 (m)	STO	0	3	
		D (m)	STO	0	4	
		Z (m)	STO	1	2	
		VPH	X			
		EF(gm/mi)	=	STO	1	
			3			
2	Execute		CLR			
		AMB (ppm)	A			CSUM (ppm)
3	Additional Runs					
	a. Check status of dispersion curve program inputs					
	b. Re-initialize L_1	L_1 (m)	STO	0	2	
	c. Store altered inputs					
	d. Go to Step 2					

USER DEFINED KEYS	DATA REGISTERS			LABELS (Op 08)
A Execute	0	10 CSUM	20 Y(i)	INV ✓ lnx ✓ CE ✓ CLR ✓ x⇌t ✓ x² ✓
B	1 PHI	11 FET see 392	21 LIM 1/WT(i)	√x ✓ 1/x ✓ STO ✓ RCL ✓ SUM ✓ yˣ ✓
C	2 L_1	12 Z	22 T	EE ✓ (✓)
D	3 L_2	13 VPH*EF	23 EN2	
E	4 D	14 H	24 EM2	
A' Used	5 SGY	15 W2	25 p	
B' Used	6 SGZ	16 PZ1	26 a_1	
C' Used	7 INTG (i+1)	17 PZ2	27 a_2	
D'	8 INTG (i)	18 PY1	28 a_3	
E'	9	19 PY2	29 24×10^9	

FLAGS	0	1	2	3	4	5	6	7	8	9
	✓	✓								

1014985-1

TITLE CALINE3 - MAIN PROGRAM PAGE 2 OF 4

PROGRAMMER Paul Benson DATE 2/80

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
000	76	LBL	
001	11	A	
002	42	STO	
003	10	10	
004	43	RCL	
005	15	15	
006	32	X:T	
007	43	RCL	
008	01	01	
009	37	P/R	
010	22	INV	
011	77	GE	
012	53	(	
013	32	X:T	EN2
014	76	LBL	
015	53	(	
016	42	STO	
017	23	23	
018	75	-	
019	32	X:T	
020	95	=	
021	50	I×I	EM2
022	42	STO	
023	24	24	
024	29	CP	
025	43	RCL	
026	02	02	L_1
027	77	GE	
028	22	INV	
029	55	÷	
030	53	(	
031	43	RCL	
032	15	15	
033	65	×	
034	02	2	
035	54	)	
036	42	STO	
037	11	11	
038	95	=	
039	75	-	
040	93	.	
041	05	5	
042	95	=	
043	59	INT	
044	65	×	
045	43	RCL	
046	11	11	
047	76	LBL	
048	22	INV	
049	85	+	
050	43	RCL	
051	15	15	
052	95	=	
053	76	LBL	
054	42	STO	

LOC	CODE	KEY	COMMENTS
055	42	STO	ECLD
056	02	02	
057	22	INV	
058	86	STF	
059	00	00	
060	29	CP	
061	77	GE	
062	23	LNX	
063	86	STF	
064	00	00	
065	76	LBL	
066	23	LNX	
067	32	X:T	
068	43	RCL	
069	04	04	
070	22	INV	
071	87	IFF	
072	00	00	
073	24	CE	
074	32	X:T	
075	76	LBL	
076	24	CE	
077	22	INV	
078	37	P/R	
079	50	I×I	
080	32	X:T	
081	42	STO	
082	07	07	
083	43	RCL	
084	01	01	
085	77	GE	
086	25	CLR	
087	87	IFF	
088	00	00	Bypass
089	32	X:T	Element
090	76	LBL	
091	25	CLR	
092	75	-	
093	32	X:T	
094	95	=	
095	50	I×I	
096	32	X:T	
097	43	RCL	
098	07	07	
099	32	X:T	
100	37	P/R	
101	87	IFF	
102	00	00	
103	33	X²	
104	32	X:T	
105	76	LBL	
106	33	X²	
107	42	STO	FET, YE
108	11	11	
109	45	YX	

LOC	CODE	KEY	COMMENTS
110	43	RCL	
111	19	19	
112	65	×	
113	43	RCL	
114	18	18	
115	95	=	SGY
116	42	STO	
117	05	05	
118	43	RCL	
119	11	11	
120	45	YX	
121	43	RCL	
122	17	17	
123	65	×	
124	43	RCL	
125	16	16	
126	95	=	SGZ
127	42	STO	
128	06	06	
129	00	0	
130	42	STO	
131	11	11	
132	43	RCL	
133	23	23	EN2
134	65	×	
135	02	2	
136	85	+	
137	32	X:T	YE
138	85	+	
139	43	RCL	
140	24	24	
141	95	=	Y(1)
142	42	STO	
143	20	20	
144	00	0	
145	22	INV	
146	86	STF	
147	00	00	
148	22	INV	
149	86	STF	
150	01	01	
151	71	SBR	
152	16	A'	
153	43	RCL	
154	23	23	
155	71	SBR	
156	16	A'	
157	04	4	1/WT(1)
158	71	SBR	
159	17	B'	

MERGED CODES

62 | 72 STO | 83 GTO
63 | 73 RCL | 84
64 | 74 SUM | 92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TITLE CALINE3 - MAIN PROGRAM PAGE 3 OF 4

PROGRAMMER Paul Benson DATE 2/80

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
160	43	RCL	
161	23	23	
162	71	SBR	
163	16	A'	
164	04	4	
165	55	÷	
166	03	3	
167	95	=	1/WT(2)
168	71	SBR	
169	17	B'	
170	43	RCL	
171	24	24	
172	65	×	
173	02	2	
174	95	=	
175	71	SBR	
176	16	A'	
177	01	1	1/WT(3)
178	71	SBR	
179	17	B'	
180	43	RCL	
181	23	23	
182	71	SBR	
183	16	A'	
184	04	4	
185	55	÷	
186	03	3	
187	95	=	1/WT(4)
188	71	SBR	
189	17	B'	
190	43	RCL	
191	23	23	
192	71	SBR	
193	16	A'	
194	04	4	1/WT(5)
195	71	SBR	
196	17	B'	
197	43	RCL	
198	29	29	
199	49	PRD	
200	11	11	
201	43	RCL	
202	06	06	SGZ
203	22	INV	
204	49	PRD	
205	11	11	
206	43	RCL	
207	13	13	
208	35	1/X	
209	32	X:T	
210	43	RCL	
211	01	01	
212	37	P/R	
213	77	GE	
214	34	ΓX	

LOC	CODE	KEY	COMMENTS
215	32	X:T	
216	76	LBL	
217	34	ΓX	
218	22	INV	QE
219	49	PRD	
220	11	11	
221	43	RCL	
222	12	12	
223	85	+	
224	43	RCL	
225	14	14	
226	95	=	
227	71	SBR	
228	18	C'	EXP1
229	32	X:T	
230	43	RCL	
231	12	12	
232	75	-	
233	43	RCL	
234	14	14	
235	95	=	
236	71	SBR	
237	18	C'	EXP2
238	85	+	
239	32	X:T	
240	95	=	
241	65	×	
242	43	RCL	
243	11	11	
244	95	=	
245	44	SUM	
246	10	10	
247	76	LBL	
248	32	X:T	
249	43	RCL	
250	03	03	L_2
251	32	X:T	
252	43	RCL	
253	15	15	
254	65	×	
255	02	2	
256	85	+	
257	43	RCL	
258	02	02	
259	95	=	
260	77	GE	ECLD, L_2
261	35	1/X	
262	32	X:T	
263	43	RCL	
264	10	10	CSUM
265	66	PAU	
266	32	X:T	
267	61	GTO	Next
268	42	STO	Element
269	76	LBL	

LOC	CODE	KEY	COMMENTS
270	35	1/X	
271	43	RCL	
272	10	10	
273	91	R/S	End
274	98	ADV	
275	76	LBL	
276	16	A'	
277	22	INV	
278	44	SUM	
279	20	20	
280	43	RCL	
281	07	07	INTG (1)
282	42	STO	
283	08	08	
284	29	CP	
285	43	RCL	
286	20	20	Y(1)
287	77	GE	
288	43	RCL	
289	86	STF	
290	00	00	
291	76	LBL	
292	43	RCL	
293	55	÷	
294	43	RCL	
295	05	05	
296	95	=	
297	50	IxI	LIM
298	42	STO	
299	21	21	
300	65	×	
301	43	RCL	
302	25	25	
303	85	+	
304	01	1	
305	95	=	
306	35	1/X	T
307	42	STO	
308	22	22	
309	45	Y^X	
310	03	3	
311	65	×	
312	43	RCL	
313	28	28	
314	85	+	
315	53	(	
316	43	RCL	
317	22	22	
318	33	X^2	
319	65	×	

MERGED CODES

62 | 72 STO | 83 GTO
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TEXAS INSTRUMENTS INCORPORATED

TITLE CALINE3 - MAIN PROGRAM PAGE 4 OF 4

PROGRAMMER Paul Benson DATE 2/80

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
320	43	RCL	
321	27	27	
322	54	)	
323	85	+	
324	53	(	
325	43	RCL	
326	22	22	
327	65	×	
328	43	RCL	
329	26	26	
330	54	)	
331	95	=	
332	65	×	
333	53	(	
334	43	RCL	
335	21	21	
336	33	X^2	
337	55	÷	
338	02	2	
339	94	+/-	
340	54	)	ARG
341	22	INV	
342	23	LNX	
343	95	=	$\sqrt{2\pi}$*
344	42	STO	INTG(1+1)
345	07	07	
346	92	RTN	
347	16	A'	
348	76	LBL	
349	17	B'	
350	42	STO	
351	21	21	1/WT(1)
352	43	RCL	
353	07	07	INTG(1+1)
354	87	IFF	
355	00	00	
356	44	SUM	
357	76	LBL	
358	52	EE	
359	75	-	
360	43	RCL	
361	08	08	
362	95	=	
363	50	I×I	PD*$\sqrt{2\pi}$
364	61	GTO	
365	45	Y^X	
366	76	LBL	
367	44	SUM	
368	87	IFF	
369	01	01	
370	52	EE	
371	85	+	
372	43	RCL	
373	08	08	
374	95	=	

LOC	CODE	KEY	COMMENTS
375	94	+/-	
376	85	+	
377	53	(	
378	89	π	
379	65	×	
380	02	2	
381	54	)	
382	34	√X	
383	95	=	PD*$\sqrt{2\pi}$
384	86	STF	
385	01	01	
386	76	LBL	
387	45	Y^X	
388	55	÷	
389	43	RCL	
390	21	21	
391	95	=	FAC2*
392	44	SUM	$\sqrt{2\pi}$ /BE
393	11	11	
394	92	RTN	
395	17	B'	
396	76	LBL	
397	18	C'	
398	55	÷	
399	43	RCL	
400	06	06	
401	33	X^2	
402	55	÷	
403	02	2	
404	95	=	
405	94	+/-	
406	22	INV	
407	23	LNX	
408	92	RTN	
409	18	C'	

LOC	CODE	KEY	COMMENTS

MERGED CODES

62 · 72 STO · 83 GTO
63 · 73 RCL · 84
64 · 74 SUM · 92 INV SBR

TEXAS INSTRUMENTS

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
FHWA/CA/TL-79/23		

4. TITLE AND SUBTITLE	5. REPORT DATE / 6. PERFORMING ORGANIZATION CODE
CALINE3 - A VERSATILE DISPERSION MODEL FOR PREDICTING AIR POLLUTANT LEVELS NEAR HIGHWAYS AND ARTERIAL STREETS	November 1979
7. AUTHOR(S)	**8. PERFORMING ORGANIZATION REPORT NO.**
Paul E. Benson	19701-604167
9. PERFORMING ORGANIZATION NAME AND ADDRESS	**10. WORK UNIT NO. / 11. CONTRACT OR GRANT NO.**
Office of Transportation Laboratory California Department of Transportation Sacramento, California 95819	A-8-46
12. SPONSORING AGENCY NAME AND ADDRESS	**13. TYPE OF REPORT & PERIOD COVERED / 14. SPONSORING AGENCY CODE**
California Department of Transportation Sacramento, California 95807	Interim

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. This study was entitled: "Distribution of Air Pollutants Within the Freeway Corridor".

16. ABSTRACT

Development and use of the 3rd generation California Line Source Dispersion Model, CALINE3, is described. This model can be used to predict carbon monoxide concentrations near highways and arterial streets given traffic emissions, site geometry and meteorology. The model has adjustments for averaging time and surface roughness, and can handle up to 20 links and 20 receptors. It also contains an algorithm for deposition and settling velocity so that particulate concentrations can be predicted. Detailed sensitivity and verification analyses are contained in the report. Also, user instructions containing four example applications of the model are included.

The model is available in FORTRAN and BASIC languages. An abbreviated version for use on HP-67/97 and TI-59 programmable calculators is also listed in the report.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Air pollution, air quality, highways, transportation, Gaussian model, dispersion, carbon monoxide, line source.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified		

DS-TL-1242 (Rev.6/76)